THE FUNGI WHICH CAUSE PLANT DISEASE

F. L. STEVENS

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TO

MY WIFE

ADELINE CHAPMAN STEVENS

IN ACKNOWLEDGMENT

OF

HELP, ENCOURAGEMENT

AND INSPIRATION

PREFACE

This volume is intended to introduce to the student the more important cryptogamic parasites affecting economic plants in the United States, with sufficient keys and descriptions to enable their identification. Technical description of each division, order, family, genus and species when important is given unless the essential characters are to be clearly inferred from preceding keys or text. Gross descriptions of the host as diseased, i. e., of the disease itself, have been avoided since such are to be found in "Diseases of Economic Plants." Effort has been made to avoid duplication of matter contained in that volume. Abundant citations to the more important papers are given, sufficient, it is believed, to put the student in touch with the literature of the subject.

While many parasites not yet known in the United States are briefly mentioned, especially the more important ones or those which are likely to invade America, no attempt has been made to list all of these. Non-parasitic groups closely related to those that are parasitic have been introduced in the keys merely to give a larger perspective to the student.

Effort has been made to give at least one illustration of each genus that is of importance in the United States.

The author is indebted for descriptions, keys, etc., to the various standard works. Those which have been drawn upon most largely are Saccardo's Sylloge Fungorum, Die Natürlichen Pflanzenfamilien of Engler & Prantl, Clinton's Ustilaginales of North America, Clement's Genera of Fungi, and Minnesota Mushrooms, Plowright's British Uredineæ and Ustilagineæ, Arthur and Murrill each in North American Flora.

The author wishes also to express thanks for suggestions and criticism of the manuscript to T. H. Macbride, who read the portion on Myxomycetes; J. J. Davis, Phycomycetes; L. R. Jones

and T. J. Burrill, Bacteria; G. M. Reed, Perisporiales; G. P. Clinton, Ustilaginales; J. L. Sheldon, Ascomycetes in part; D. Reddick, Ascomycetes in part; J. C. Arthur, Uredinales; F. D. Heald, Fungi Imperfecti in part; F. C. Stewart, Fungi Imperfecti in part; H. Metcalf, Basidiomycetes in part; to Mrs. Flora W. Patterson for aid in securing descriptions otherwise unobtainable; to Dr. Marshall Avery Howe for assistance with the glossary; to Messrs. Norton, Rosenkranz and Fawcett, for aid in proof-reading and in preparation of the manuscript, though no responsibility for error attaches to those who have so kindly aided.

It is probable, owing to the present unsatisfactory condition of taxonomy of the fungi, loose and imperfect description of species, disregard of generic limitation, lack of knowledge regarding the limits of specific variation, influence of environment, biologic host relations, etc., that many of the species treated in the text are untenable. The author has, however, attempted so far as possible to reflect the facts as they appear in the light of present knowledge and has deemed it more useful to err on the side of conservatism than to attempt to reduce the apparent number of species by consolidation without full and complete evidence as to the real identity of the species in question.

F. L. STEVENS.

MAYAGÜEZ, Porto Rico.

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THE FUNGI WHICH CAUSE PLANT DISEASE

INTRODUCTION

The principal non-flowering vegetable parasites which cause plant diseases belong to three divisions: the **Slime Molds** (**Myxomycetes**); the **Bacteria** (**Schizomycetes**); and the **True Fungi** (**Eumycetes** including the Phycomycetes). The term **fungi, in the broad sense,** is often used to include all three of these divisions. All are devoid of chlorophyll and therefore all differ from the green plants in the essential ways which result from this deficiency. Transpiration, respiration, and true assimilation are the same as with the green plants, but photosynthesis or starch manufacture cannot be accomplished by them. Sunlight being thus useless to them directly they can live in the dark as well as the light. Having no ability to elaborate their own foods from inorganic matter these organisms are limited to such nutriment as they can obtain from plants or animals which have elaborated it; that is, they must have organic foods for their sustenance.

The fungi have acquired various food habits and adapted themselves to different methods of nutrition. Some are nearly omnivorous and can subsist upon almost any decaying tissue or upon soils or solutions rich with organic debris. Others thrive only upon special substances, as for example, some particular plant or animal, **the host,** perhaps only upon some particular part of that plant or animal. The organisms that prey upon living things are called **parasites.** Those living upon dead things are **saprophytes.** No hard and fast line can be drawn between these two classes. An organism which is usually a saprophyte may live upon a dead member of some plant, gradually encroach upon the still living part and thus become partially a parasite. Again there are times in the history of a plant when life ebbs so low that it is difficult to tell the living from the dead. The pulp of the apple

when ripe, a resting seed, the cells of the potato tuber in winter, are undoubtedly alive, yet their activity is so little that many organisms can gain a foothold upon these stages of the plant that cannot do so at more vigorous periods of their existence.

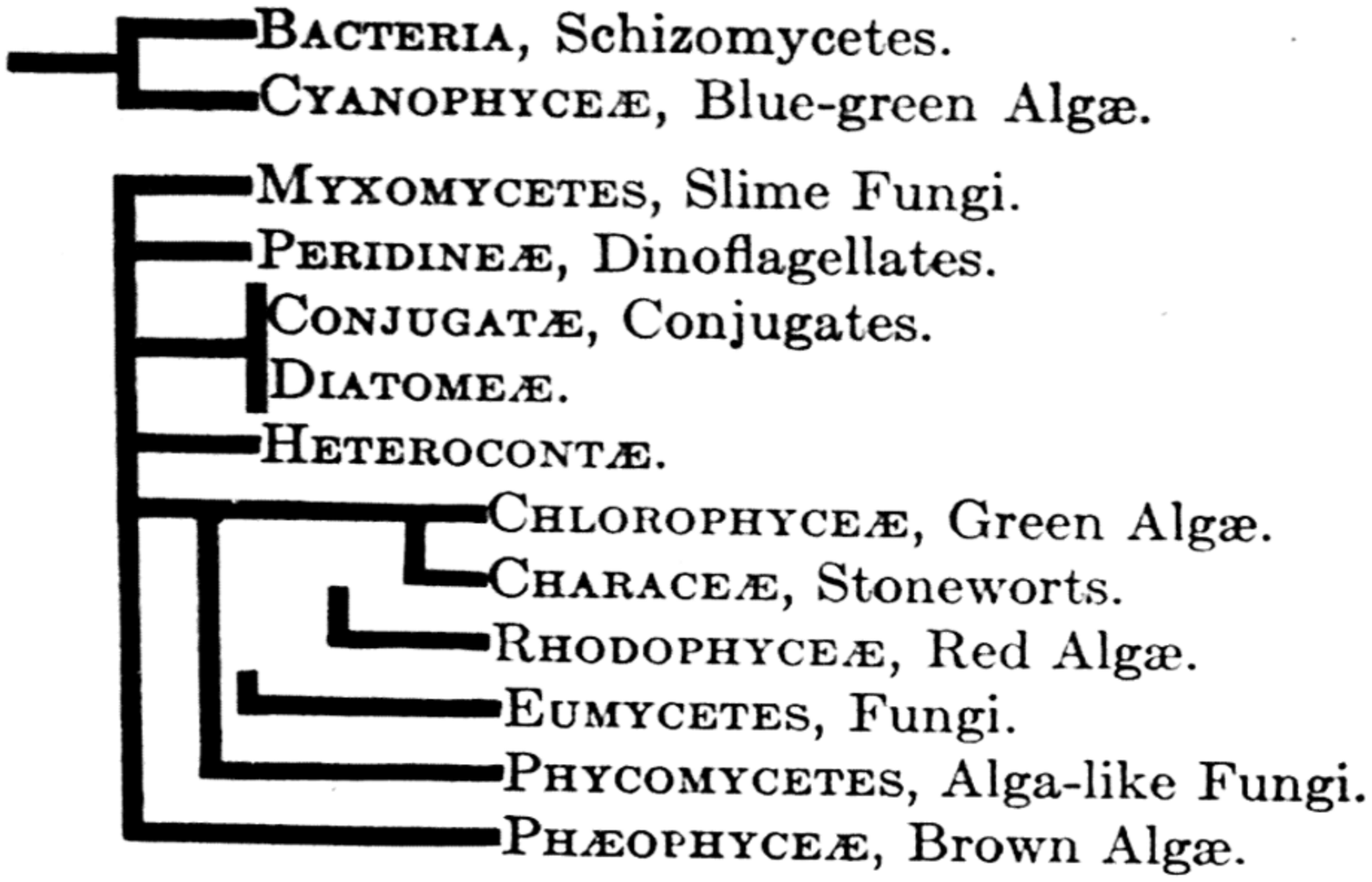
Tubeuf [27] ranks as **hemi-parasites** those organisms that usually are parasites, but may sometimes become saprophytic, and as **hemi-saprophytes** such as are usually parasitic, but may exceptionally become saprophytic. These distinctions are of little import, other than to bring out clearly that each species has its own limits as to food requirements.

It is hardly to be thought that these parasites and saprophytes have always been dependent organisms. The true fungi for example are best to be regarded as degraded descendants of algæ, in which ancestors they once possessed chlorophyll and could prepare their own food from mineral matter by the aid of sunlight.

No discussion of the general metabolic processes of the fungi is here necessary further than to indicate that among the products of their activity there are various excretions and secretions, which bear important relations to parasitism. Thus certain fungi growing in artificial culture produce **enzymes or organic ferments** capable of softening and dissolving cellulose, also **toxins,** poisons which are capable of killing the cells of the host plant. Such enzymes and toxins are numerous and their bearing upon parasitism is obvious. They enable the parasite to kill adjacent cells of the host and then to effect an entrance through the cell walls to the protoplasm and other nutrients contained within the cell.

The presence of the parasite, or secretions produced by it, often calls forth abnormal growth responses from the host. These take very diverse forms, either the undergrowth or overgrowth, hypertrophy, of single cells or tissues, or even the excessive development of large plant parts as in the case of the witches' brooms, and the "double flowering" of the dewberry.

The probable relations of the groups under consideration to the other members of the Thallophyta are suggested in the following scheme.[30]



Key to the **three Divisions** important as plant parasites:

Vegetative body a multinucleate naked plasmodium **Division I. Myxomycetes,** p. 5.

Vegetative body a single-walled cell, nucleus absent or not of the form typical in the other fungi, reproduction by fission (by conidia in a few non-parasitic forms)...**Division II. Schizomycetes,** p. 13.

Not as above: Vegetative body usually filamentous, reproduction by various means.....**Division III. Eumycetes,** p. 59.

DIVISION I

MYXOMYCETES, SLIME MOLDS, SLIME FUNGI[40-44] (p. 3)

These are the lowest organisms considered by the botanist, and partake so much of the nature of both animals and plants that their position has long been debated. Their affinities are with the lowest living things, on the boundary between the animal and the vegetable kingdom, and sometimes more attention is accorded them by the zoölogist than by the botanist.

The distinctive character of this group is that the vegetative condition consists either of distinct amœboid cells or of a mass of naked protoplasm, the **plasmodium,** composed of numerous cell units, each unwalled. The plasmodia, at the completion of the free vegetative stage, produce numerous walled spores either free or in sporangia of various forms. The spores upon germination produce either zoöspores or amœboid bodies which multiply and unite to form either new plasmodia or pseudoplasmodia.

The slime molds consist of three orders:

Key to Orders of Myxomycetes

Parasitic ..... 1. **Plasmodiophorales,** p. 5.
Saprophytic
Vegetative phase of free amœbæ ..... 2. **Acrasiales**
Vegetative phase plasmodial..... 3. **Myxogastrales,** p. 9.

The Acrasiales contain some five genera and ten species purely saprophytic.

Plasmodiophorales

Intracellular parasites; vegetative stage plasmodial; spores formed by the simultaneous breaking up of the plasmodium into an indefinite number of independent cells.

The Plasmodiophorales appear to include all of the true parasites of the Myxomycetes.

KEY TO GENERA OF **Plasmodiophorales**

Spores free, spherical . . . . . 1. **Plasmodiophora,** p. 6.
Spores united into groups
  Spores in groups of four . . . . . 2. **Tetramyxa,** p. 8.
  Spores in larger groups
    Spores forming a hollow sphere. . . . 3. **Sorosphæra,** p. 8.
    Spores forming a spongy spore-ball 4. **Spongospora,** p. 8.

Plasmodiophora Woronin

This genus is parasitic in the living parenchyma of the roots of plants, the plasmodia filling the cells and causing galls at the point of attack. There are three species of the genus in Europe and America.

P. brassicæ Wor.[1–6, 200–203, 208] has long been known as a parasite on the crucifers generally and recent work indicates that other families, as the Umbelliferæ and cucurbs, are also susceptible.[199]

The parasitised cells especially, and the adjacent cells as well, are stimulated to enormous overgrowth; this hypertrophy resulting in a characteristic root "clubbing."

Study of diseased sections shows that the medullary rays and cortex are abnormally thick (hypertrophy and hyperplasia) and many of their cells are parasitized. Sclerenchyma cells are suppressed by the parasite and the xylem is reduced and phloem increased proportionately. The amount of stored starch is much less than in normal tissues.

Infection does not appear to pass from cell to cell but groups of diseased cells are thought to arise from repeated division of a cell after its infection.

In the enlarged host cells the protoplasm appears abnormally dense and fine grained. Eventually the whole lumen of the cell is occupied by the crowded, amœboid, individuals, each uninucleate and unwalled, and still distinct from the other. These individuals later fuse into a plasmodium the nuclei of which enlarge and undergo simultaneous mitotic division. Still later the mass divides into uninuclear segments each of which matures to a spore 1.6 μ in diameter, covered by a thin, smooth, colorless membrane.

The decay of the host liberates the spores in the soil. Their germination may be readily studied upon a microscope slide where in from five to twenty-four hours uninucleate zoöspores are produced. The zoöspores are differentiated into an inner

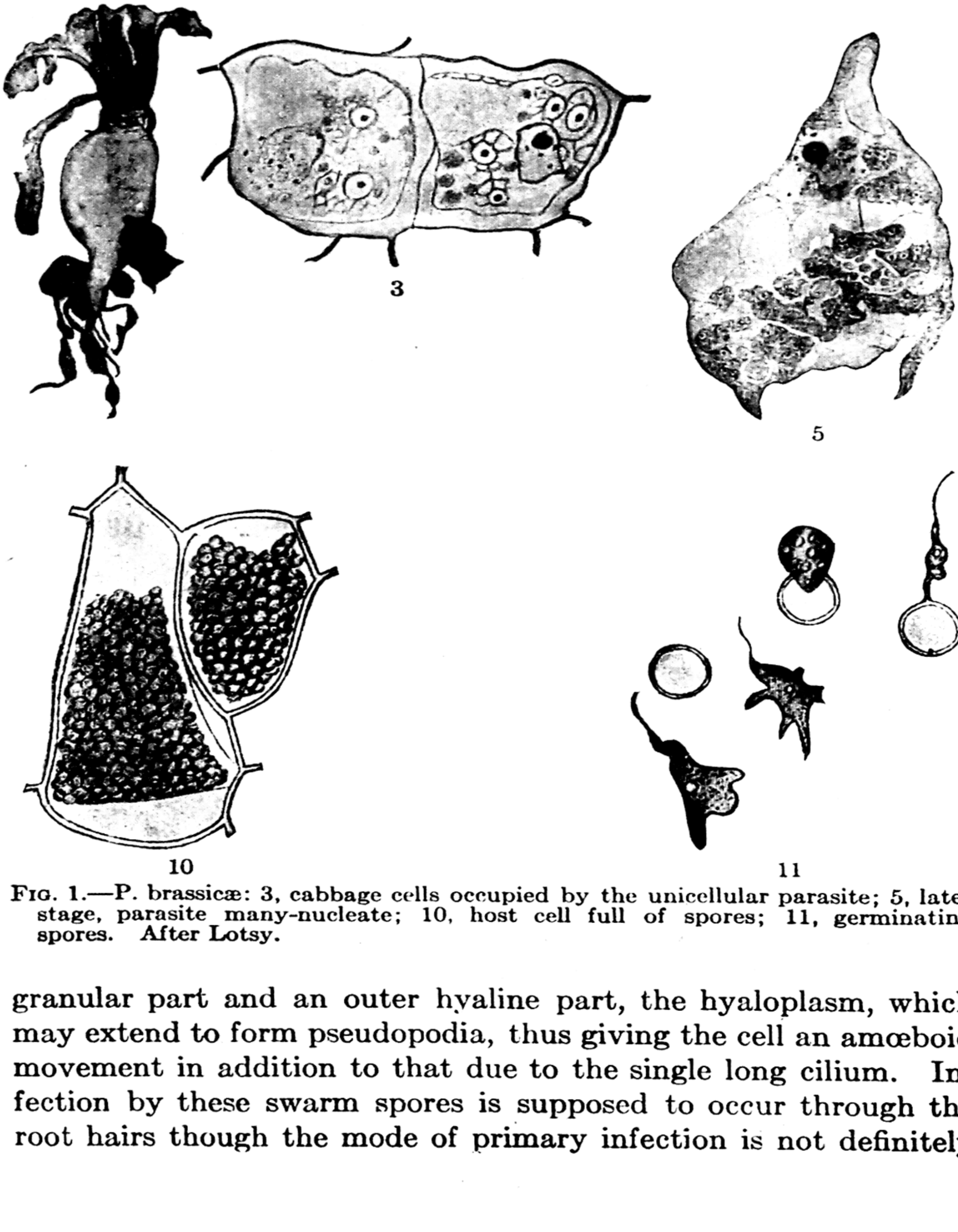


FIG. 1.—P. brassicæ: 3, cabbage cells occupied by the unicellular parasite; 5, later stage, parasite many-nucleate; 10, host cell full of spores; 11, germinating spores. After Lotsy.

granular part and an outer hyaline part, the hyaloplasm, which may extend to form pseudopodia, thus giving the cell an amœboid movement in addition to that due to the single long cilium. Infection by these swarm spores is supposed to occur through the root hairs though the mode of primary infection is not definitely

known. Seedlings raised in soil inoculated with chopped roots bearing the disease become badly diseased as do also seedlings upon which infected water is poured.

P. humili Kirk is mentioned by Kirk [7] as the cause of club root of hops in New Zealand.

P. vitis Viala & Sauvageau; [8] **P. californica** Viala & Sauvageau; [9] **P. orchidis** Massee [10] and **P. tomato** Abbey [11] have been reported as the causes of serious diseases but their relation to the diseases and even their identity as actual organisms is seriously questioned.[12-14]

Tetramyxa Goebel grows upon water plants, notably Ruppia.[8]

Sorosphæra Schröter (p. 6)

Parasitic in the parenchyma of living plants; spores elliptic-wedge shaped, forming a hollow, spherical spore ball.

One species is found upon Veronica;[8] a second species has been reported upon tea.[15]

S. graminis Schwartz is reported by Schwartz [187] on the roots of Poa and other grasses where it caused nodules much resembling those of nematodes.

Spongospora Brunchorst (p. 6)

Similar to Sorosphæra but the spores forming a spore ball with open reticulations.

S. subterranea (Wallr.) Lag.[17-19] causes the powdery scab of potatoes in Great Britain, Europe and South America. It has been closely studied by Osborne [16] who shows it to appear first in the tuber cells as a uninucleate myxamœba which ultimately develops into a multinucleate amœboid plasmodium.

Sorolpidium Nemec is a new genus with the species.

S. betæ Nemec which is on beets.[188]

Several little known genera, kin to the above, attack algæ, fungi, pollen, etc.

Pseudomonas radicicola, the legume tubercle organism has been by some placed in this order under the name Phytomyxa leguminosarum.

Myxogastrales (p. 5)

This order comprises some forty-seven genera and four hundred species of great variety and beauty. The plasmodium, which varies from a millimeter or less to several decimeters in diameter, produces either flat encrusted masses of spores, **æthalia,** or develops spores in sporangia which show some superficial resemblance to very small puffballs, Fig. 2. The interior of the sporangium is often permeated by a thread-like structure, the **capillitium.** They are not parasites but occasionally injure plants by overgrowing them.

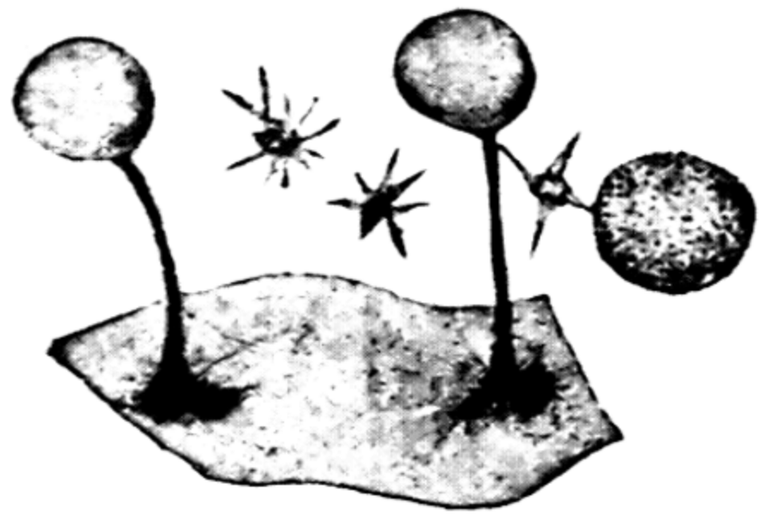


FIG. 2.—Sporangia of Didymium; spore; calcareous crystals. After Macbride.

KEY TO FAMILIES OF Myxogastrales

Spores not enclosed in a sporangium, borne externally upon the fruiting bodies. . . . 1. **Ceratiomyxaceæ.**

Spores enclosed in a sporangium

Capillitium wanting, or very poorly developed

Periderm of uniform thickness, rupturing irregularly . . . . . 2. **Liceaceæ.**

Periderm of unequal thickness

Periderm with a subapical thin line, opening by an operculum . . . . . 3. **Orcadellaceæ.**

Periderm unequally thick above, the thin portions evanescent, leaving a network formed by the thicker portions . . . . . 4. **Cribrariaceæ.**

Capillitium well developed

Calcareous deposits absent, or rarely present in the periderm

Capillitium of hollow, usually sculptured threads; spores light colored 5. **Trichiaceæ.**

Capillitium of solid, smooth and usually much branched threads; spores dark colored

Fruiting bodies æthalioid or in-

definite, walls poorly defined, fraying out into a pseudo-capillitium..... 6. **Reticulariaceæ.**
Sporangia definite, true capillitium more or less prominent 7. **Brefeldiaceæ.**
Fruiting bodies separate sporangia with columella and abundant capillitium..... 8. **Stemonitaceæ.**
Calcareous deposits present
Capillitium not calcareous
Capillitium simple ..... 9. **Didymiaceæ,** p. 10.
Capillitium more intricate..... 10. **Spumariaceæ,** p. 11.
Fructification calcareous throughout 11. **Physaraceæ,** p. 11.

Didymiaceæ

Fructification of separate sporangia or plasmodiocarps, periderm simple or double, the outer calcareous; columella present or absent; capillitial threads thin, colorless or violet, arising from the base of the sporangium or passing from the columella to the periderm, usually without calcareous deposits, which if present are very small crystals; spores in mass black, spore walls violet.

Key to Genera of **Didymiaceæ**

Calcareous deposits in the form of stellate crystals, frosting the surface..... 1. **Didymium,** p. 10.
Calcareous deposits not stellate,
Calcareous deposits forming a superficial crust 2. **Diderma.**
Calcareous deposits forming large superficial scales..... 3. **Lepidoderma.**

Didymium Schröter

Sporangia distinct, stipitate, sessile or even plasmodiocarpous, never æthalioid; the peridium thin, irregular in dehiscence, covered with a more or less dense coating of calcareous crystals; columella more frequently present; capillitium of delicate threads, simple or sparingly branched, extending from the columella to the peridial wall.

D. dædalium. B. & Br. is occasionally injurious to melons in culture.[20]

Spumariaceæ (p. 10)

Sporangia separate or æthalioid; calcarious deposit in the periderm or columella, never in the capillitium; capillitium radiating from various points of the columella, branching and anastomosing to form a network, the ultimate branchlets of which support the periderm.

Key to Genera of Spumariaceæ

Fructification of ordinary sporangia	1. **Diachea.**
Fructification æthalioid	2. **Spumaria,** p. 11.

Spumaria Persoon

Fructification æthalioid, consisting generally of large cushion-shaped masses covered without by a white foam-like crust; within, composed of numerous tubular sporangia, developed from a common hypothallus, irregularly branched, contorted and more or less confluent; the peridial wall thin, delicate, frosted with stellate lime crystals, which mark in section the boundaries of the several sporangia; capillitium of delicate threads, generally only slightly branched, terminating in the sporangial wall, marked with occasional swellings or thickenings.

S. alba (Bul.) D. C. Like all other members of the order the present species is not a parasite but its æthalia are frequently produced upon grass, strawberries [21] and other plants in such abundance as to cause more or less serious injury. The sporangia are fused into a large æthalium which is white or cream-colored, from 1 to 7 cm. long and half as thick.

Physaraceæ (p. 10)

Key to Genera of Physaraceæ

Fructification æthalioid	1. **Fuligo,** p. 12.
Fructification plasmodiocarpous or of distinct sporangia	
Peridium without lime	
Plasmodiocarpous	2. **Cienkowskia.**
Sporangia distinct	3. **Leocarpus.**
Peridium calcareous, more or less throughout	
Capillitium calcareous throughout	4. **Badhamia.**

Capillitium in part hyaline
  Sporangium vaselike, or more or less tubular
    Opening irregularly. . . . . 5. **Physarella.**
    Opening by a lid . . . . . 6. **Craterium.**
  Sporangia various, dehiscence irregular
    Capillitium evenly branched; the calcareous nodes small, fusiform. . . . . 7. **Tilmadoche.**
    Capillitium intricate. . . . . 8. **Physarum,** p. 12.

The species of **Fuligo** produce very large yellowish plasmodia which change to yellowish or brownish æthalia. Some are credited with damage similar to that of the preceding species.[22]

Physarum Persoon

Sporangia plasmodiocarpous, æthalioid or distinct; the peridium usually simple, sometimes double, irregularly dehiscent, more or less definitely calcareous; capillitium a uniform irregular net, dilated and calcareous at the nodes, adherent on all sides to the peridial wall.



FIG. 3.—Physarum sporangium. After Macbride.

P. cinereum (Batsch), Pers., the species most commonly reported as injurious, forms its tiny sessile, gray sporangia in great numbers on living plants,[20, 195] often smothering them. The peridium is lime charged as are also the nodes of the capillitium. The spores are brown or violet, and warty.

P. bivalve F. has been noted as injuring young bean plants.[22]

Dendrophagus globosus Toumey was reported by Toumey [23] as the probable cause of crown gall, but such relation is doubtful (p. 36). It is said to be closely related to Physarum.

DIVISION II

BACTERIA, SCHIZOMYCETES [18, 31-39] (p. 3)

Bacteria are extremely minute, unicellular organisms, which in outline present three primary forms each of great simplicity, namely the spheres (**cocci**), the straight rods (**bacteria**), the curved rods (**spirilli**).

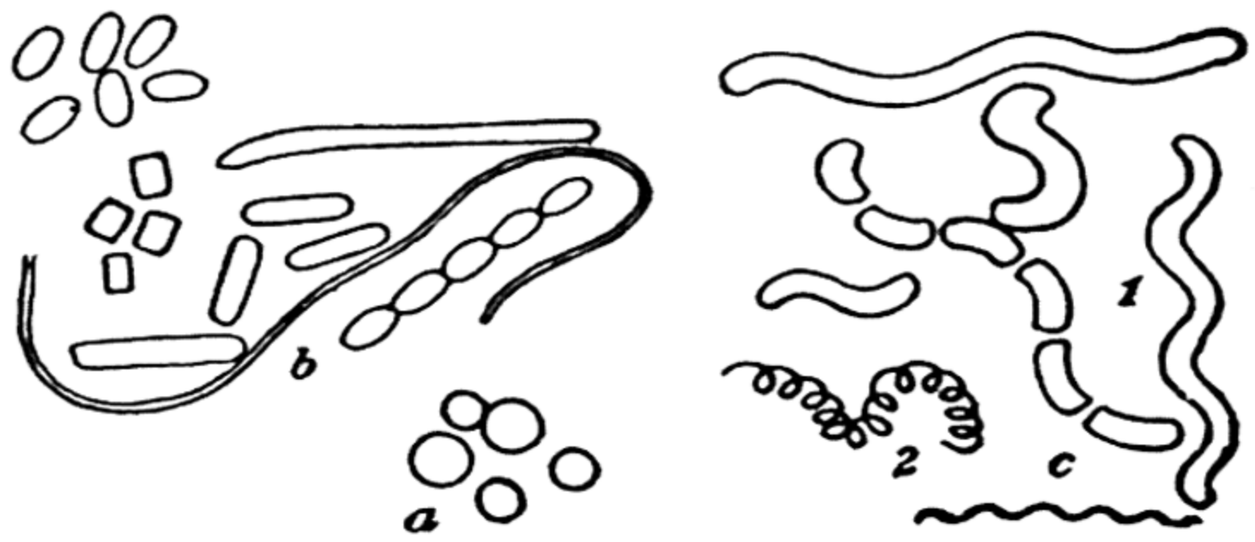


FIG. 4.—The three type forms of bacteria; *a*, spheres; *b*, rods; *c*, spirals. After Conn.

In addition to these forms which comprise the vast majority of known species of bacteria there are also bacteria consisting of filamentous bodies, either simple or branched, attached or free. In both structure and physiology bacteria are allied to the vegetable kingdom and in it most closely to the blue green algæ.

Bacteria are inconceivably small. Most of the spherical bacteria fall within the limits of from 0.5 to 1.5 μ in diameter. Among the rod and curved bacteria the length in most species is between 1 and 1.5 μ, the diameter between 0.5 and 1 μ. Among the largest species is B. megatherium, 2.5 x 10 μ; Clostridium butyricum, 3 x 10 μ; and Spirillum volutans, 13 to 50 μ long. Among the smallest is Spirillum parvum 0.1-0.3 μ in diameter and Pseudomonas indigofera 0.06 x 0.18 μ.

It is practically impossible to conceive these dimensions. An illustration may aid the imagination. The paper on which these words are printed is about 87.5 μ thick. It would therefore take about 200 bacteria of ordinary size or 400 moderately small or 20 very large ones placed end to end to equal in length the thickness of this paper. It would take 1571 ordinary bacteria (1 x 2 μ) end to end to reach around the circumference of a dot

FIG. 5.—This dot is 1 mm. in diameter.

1 mm. in diameter. (Fig. 5.) 500 to reach across it; and 392,700 placed side by side or 785,400 if placed on end to cover its area, and about 500,000,000 to fill a cube the edge of which is 1 millimeter, making no allowance for lost space of the interstices. Considerably more than 500,000,000,000 bacteria of this size would find room enough to move about in a space of one cubic centimeter.

The typical mode of increase among bacteria—the only mode except among the sheath bacteria—is by **fission or direct division** of one cell, **the mother cell,** into two, **the daughter cells.** Fig. 6. The rapidity with which fission can proceed depends of course upon conditions of environment, ranging from no growth at all, due to cold, lack of nutriment, presence of inhibiting substance, to a maximum that varies with the species. For bacteria





FIG. 6.—Diagram illustrating the fission of bacteria, bacilli and cocci. After Novy.

in general under very favorable surroundings, with proper temperature and abundance of food, from 20 to 40 minutes may be reckoned as a generation. In 24 hours, with the divisions once each hour, the progeny of one germ will be 16,777,216; with divisions each 30 minutes it will be $(16,777,216)^2$.

If cell division be in one direction only and the resulting daughter cells remain undisturbed, a thread-like row results. If cell division be in two planes, and the resulting cells adhere in groups, tablets of 8, 16, and 64 will occur frequently. If the division be in three planes and their cells adhere, packets result.

The structure of the bacterium cell owing to its minuteness is yet very incompletely known. The most enduring portion of the vegetative cell is the cell wall. This is surrounded by a layer, the **capsule** and bears the **flagella.** The number of the flagella and their position varies in different species. Some species have **none,** some one, two, or many. They may be at the ends, **polar,**

or scattered over the whole surface, **diffuse** or **peritrichiate.** They are the organs of locomotion. Within the wall is the **protoplast** consisting of a peripheral layer, inner strands, imbedded granules and **vacuoles** bearing cell sap. The existence of a nucleus comparable to that in higher plants is a much controverted point.

Spores: Typically a bacterial spore consists of a highly refractive, ovoid, walled body within the mother cell. This body possesses high resistance to ordinary stains, a great tenacity against decolorizing if it be once stained, a higher resistance against adverse temperatures and adverse conditions generally than do vegetative cells, and finally the ability to germinate and thus aid in perpetuating the species. While the absolute number of bacterial species that form spores is large, comparatively they are few. They are most frequently met among the rod forms, and are rare among the spirilla and cocci. None are known among the important plant pathogens.

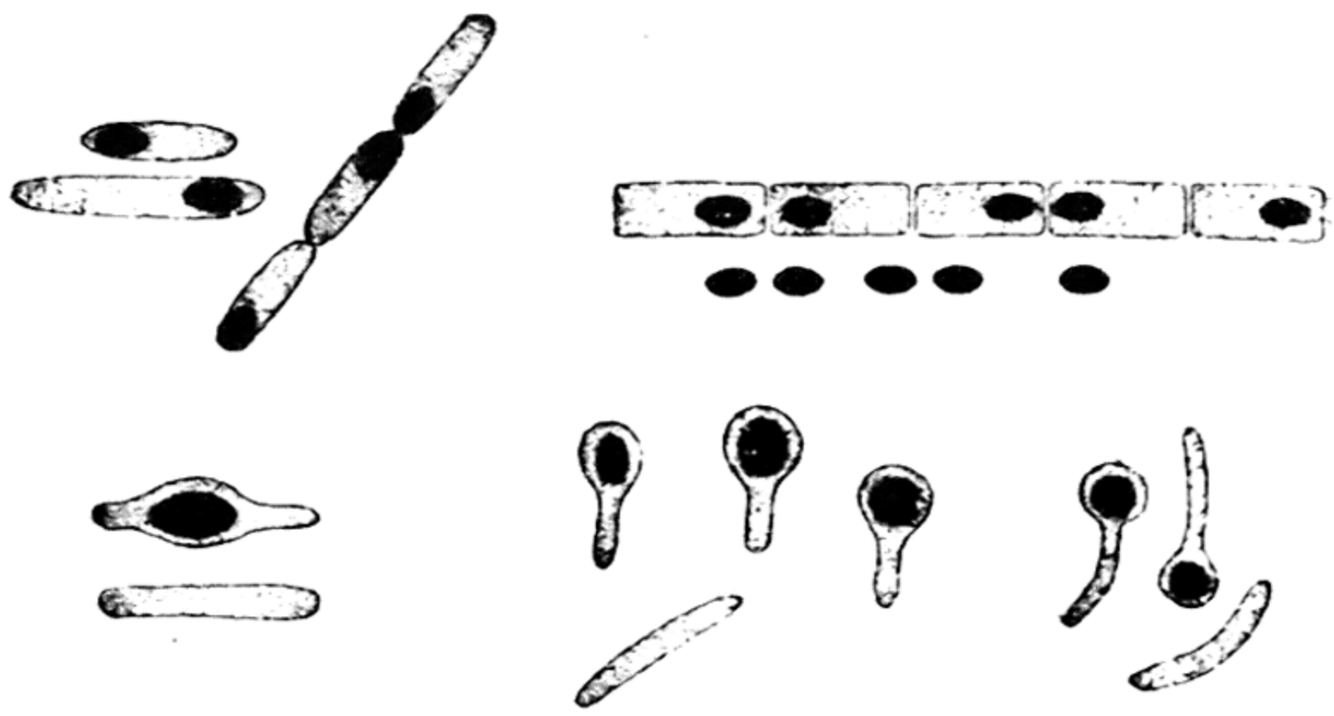


FIG. 7.—Spores of bacteria showing their position within the cells. After Frost & McCampbell.

In the simplest cases of spore formation, the protoplasm becomes more dense in some part of the mother cell, the remaining protoplasm of the cell is drawn around the denser mass, and the whole resulting dense region becomes enclosed within a special wall. Usually in this process nearly all the protoplasm of the mother cell, the **sporangium,** is used. The mother cells during spore formation may remain of the normal vegetative size and shape; they may take on (B. subtilis) or abandon (B. megatherium) the habit of thread formation. Bacteria of many species become swollen at the point where the spore develops, Figs. 7 and 9; be this in one end (Vibrio rugula) or in the middle (B. inflatus). The swelling at the end is very common, giving rise



FIG. 8.—Spore formation in bacteria. After Fischer.

to the peculiar and characteristic form known as "Nail Head" or "Drum Stick" bacteria. In nearly all species of the Eubacteria the spores are solitary.

There are three modes of **spore germination.** The most common, **polar germination,** consists in a rupture of one pole of the spore and the development of a normal vegetative cell through the opening. The second mode, **equatorial,** Fig. 9, consists in a rupture in the side instead of the end of the spore. The third mode,

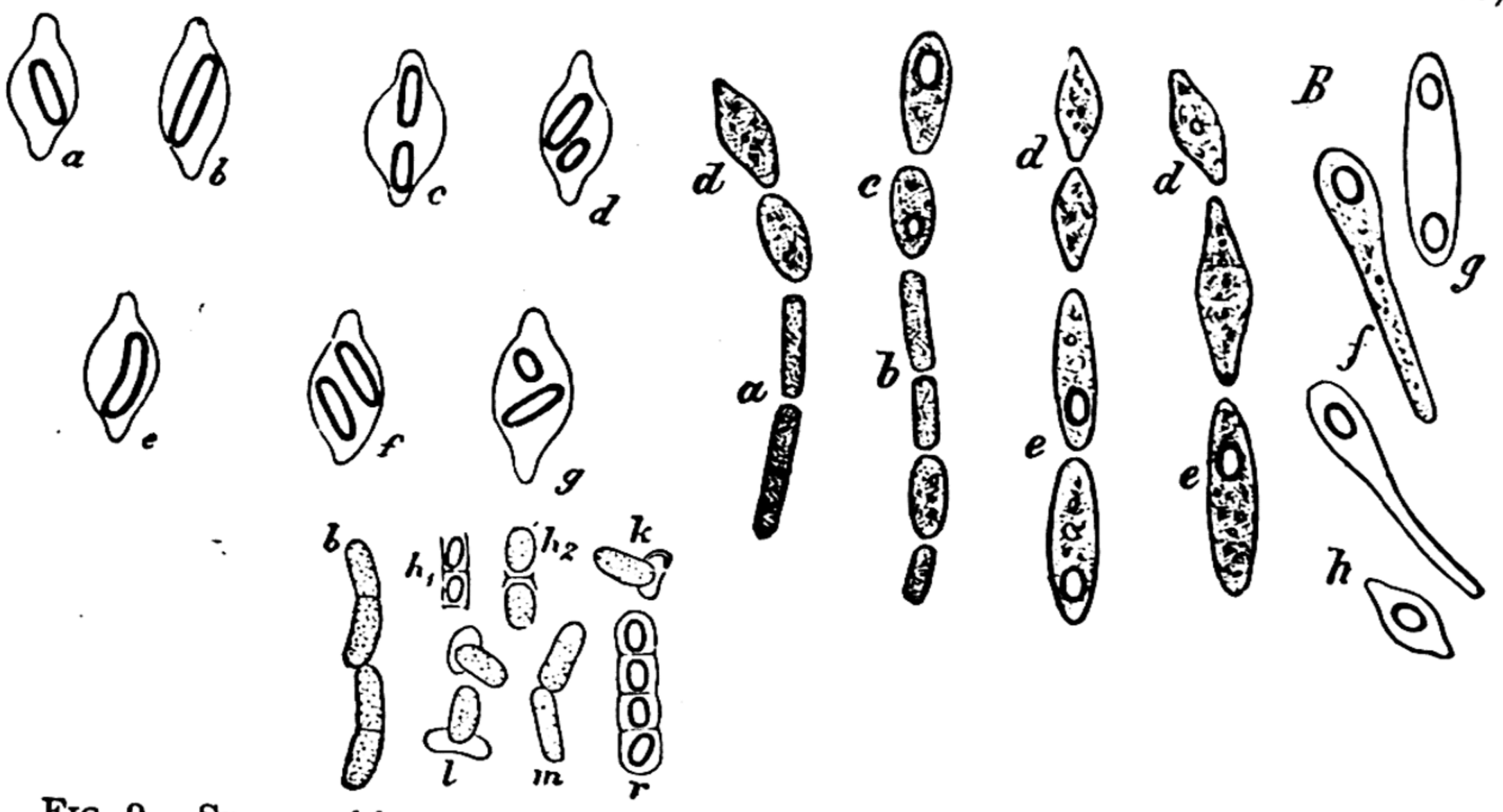


FIG. 9.—Spores of bacteria, showing bispored cells, spore formation and spore germination. After Prazmowski, De Bary and Koch.

absorption, consists in a direct development of the whole spore into a vegetative cell. In suitable environment germination may occur immediately after spore formation; if conditions be unsuitable it may be delayed for many years.

Under certain conditions most bacteria undergo abnormal changes in form becoming elongated, branched, swollen, bulged, curved, or variously, usually irregularly, distorted. Such are termed **involution forms.** They are in most cases due to unfavorable conditions of temperature and nutriment, and the bacteria resume their normal form when again in normal environment.

The branched forms found in root tubercles after the period of luxuriant growth has passed, and the branched thread-like growth of the bacterium of human tuberculosis upon artificial media, are by many regarded as involution forms.

Constancy of Species. Bacteria in nature and under artificial conditions remain true to species. There may be variation from generation to generation as among all other plants or animals of the world, and by the slow process of evolution, a species may in many generations become modified, leading eventually to new races, varieties, and possibly species. That one species can change directly and suddenly to another, much less a species of one genus into a species of another genus, is not to be credited. Marked variation is brought about in many species by change in temperature, food, oxygen supply, etc., changes in size, form, sporulation, flagellation, virulence, chromogenesis, fermentative power, grouping, etc. These changes belong to the life cycle of the species and occur as reactions to the environment.

Bacteria were discovered by **Loewenhoek** in 1683. That they do not originate spontaneously was shown by **Pasteur** in 1860–4. The first disease producing bacteria were recognized in anthrax by Pollander & Davaine in 1849; and the first definite proof that bacteria actually cause animal disease was made by **Koch** with anthrax in 1875–1878. The first plant disease to be definitely ascribed to bacteria was the pear blight by **Burrill** in 1879. The invention of the cotton plug, Schroeder & Dusch, 1853, the gelatine method of plating for the isolation of species, Koch, 1881, and the use of stains, Weigert, 1875, were practically necessary prerequisites to any considerable advance in bacteriology. For long it was contended, especially by European bacteriologists, that bacteria do not cause plant diseases but most convincing proof to the contrary was adduced by E. F. Smith.

Entrance to the host plant is made in various ways, very often through wounds, particularly wounds caused by insects, through roots, stomata, water pores, through delicate tissues as blossoms, etc. Once in the tissue, bacteria may migrate rapidly by means of the vessels, intercellular spaces or more slowly through cavities dissolved by the aid of enzymes.

Classification. In all there are some thirty-six well recognized genera embracing twelve hundred or thirteen hundred purported species of bacteria. This number will doubtless be greatly decreased when the organisms have been well studied, by finding that many so-called species are not really distinct. The number

will also of course receive many additions of forms not as yet known.

No system of classification can yet be said to have general acceptance and all classifications now in vogue will undoubtedly undergo minor changes and perhaps changes in fundamental conception.

The system of Migula[37] meets probably with most favor. With the omission of genera of little import pathologically, and with the introduction of the order Myxobacteriales, it is as follows:

SCHIZOMYCETES (p. 3)

Fission plants, without phycochrome, dividing in one, two or three directions of space. Reproduction by vegetative multiplication. Resting stages, endospores, exist in many species. Motility by means of flagella in many genera.

KEY TO ORDERS, FAMILIES, AND GENERA OF **Schizomycetes**

Cells without sulphur or bacterio-purpurein	Order I. **Eubacteriales.**
Cells in free condition gobular; in division somewhat elliptical	I. **Coccaceæ,** p. 21.
Nonflagellate	
Division in only one direction, cells single, in pairs, or chains	1. **Streptococcus.**
Division in two directions; cells may remain in plates	2. **Micrococcus,** p. 2[illegible].
Division in three directions cells may remain in bale-like packets	3. **Sarcina.**
Flagellate	
Division in two directions	4. **Planococcus.**
Division in three directions. .	5. **Planosarcina.**
Cells long or short, cylindrical, straight, division in one direction	II. **Bacteriaceæ,** p. 21.
Nonflagellate	6. **Bacterium,** p. 21.
Flagellate	
Flagella diffuse	7. **Bacillus,** p. 37.
Flagella polar	8. **Pseudomonas,** p. 22.

Cells spirally curved or representing part of a spiral, division in one direction.	III. **Spirillaceæ.**
Cells cylindric in sheathed threads. . .	IV. **Chlamydobacteriaceæ.**
Cells with sulphur. . . . . Order	II. **Thiobacteriales.**
Motile rods in pseudoplasmodial masses in a gelatinous matrix, and forming highly developed cysts. . . . . Order	III. **Myxobacteriales.**

The species of families 3 and 4 and of orders II and III, some twenty-five genera in all, are so far as is known, unimportant as regards plant disease. All of the known plant pathogens belong to one or other of the first two families of the Eubacteriales. Each of these families contains several dangerous parasites upon animals, e. g., Bacillus typhosus, Spirillum choleræ-asiaticæ, Bacterium tuberculosis.

The specific characters of bacteria are chiefly chemical or physiological and rest in the relation of the forms to oxygen, gelatine liquefaction, fermentation of various sugars, acid production, relation to nitrogenous compounds, chromogenesis, etc.[31, 37, 209]

To enable brief expression of these characters the Society of American Bacteriologists endorses the following numerical system.*

A Numerical System of Recording the Salient Characters of an Organism. (Group Number)

100.	Endospores produced
200.	Endospores not produced
10.	Aërobic (Strict)
20.	Facultative anaërobic
30.	Anaërobic (Strict)
1.	Gelatine liquefied
2.	Gelatine not liquefied
0.1	Acid and gas from dextrose
0.2	Acid without gas from dextrose
0.3	No acid from dextrose
0.4	No growth with dextrose

* This will be found useful as a quick method of showing close relationships inside the genus, but is not a sufficient characterization of any organism.

.01	Acid and gas from lactose
.02	Acid without gas from lactose
.03	No acid from lactose
.04	No growth with lactose
.001	Acid and gas from saccharose
.002	Acid without gas from saccharose
.003	No acid from saccharose
.004	No growth with saccharose
.0001	Nitrates reduced with evolution of gas
.0002	Nitrates not reduced
.0003	Nitrates reduced without gas formation
.00001	Fluorescent
.00002	Violet chromogens
.00003	Blue "
.00004	Green "
.00005	Yellow "
.00006	Orange "
.00007	Red "
.00008	Brown "
.00009	Pink "
.00000	Non-chromogenic
.000001	Diastasic action on potato starch, strong
.000002	Diastasic action on potato starch, feeble
.000003	Diastasic action on potato starch, absent
.0000001	Acid and gas from glycerine
.0000002	Acid without gas from glycerine
.0000003	No acid from glycerine
.0000004	No growth with glycerine

The genus according to the system of Migula is given its proper abbreviation which precedes the number thus: *

BACILLUS COLI (Esch.) Mig.	becomes	B.	222.111102
BACILLUS ALCALIGENES Petr.	"	B.	212.333102
PSEUDOMONAS CAMPESTRIS (Pam.) E. F. Sm.	"	Ps.	211.333151
BACTERIUM SUICIDA Mig.	"	Bact.	222.232203

* Incomplete group numbers are given with many of the species in succeeding pages. In these the known factors are given and the unknown or imperfectly known are represented by dashes. These numbers were worked out for the author by Mr. W. C. Norton, from the available literature.

The plant pathogens as yet known, with few exceptions, belong to the two genera Pseudomonas and Bacillus between which they are about equally divided.

In the earlier days of bacteriology and to some extent in recent days, bacteria have been seen in diseased plant tissues and have been placed by their observers in one genus or another and cited as the causes of the diseases in question but without actual evidence that they cause the diseases and very often without any real evidence as to the genus to which the bacteria belonged. It is of course usually impossible to identify such forms and they must be dropped from consideration.

Coccaceæ (p. 18)

No representative of this family parasitic upon plants has yet been reliably recorded in America. **Micrococcus tritici** Pril [24] upon wheat in England is probably in reality Bacillus prodigiosus and not pathogenic. **Micrococcus phytophthorus** Frank [25, 26] reported as a cause of potato rot and also associated with potato black-leg is perhaps in reality identical with Bacillus phytophthorus Appel. **Micrococcus nuclei** Roze, **M. imperiatoris** Roze, **M. flavidus** Roze, **M. albidus** Roze, **M. delacourianus** Roze and **M. pellucidus** Roze are assigned by Roze [27] as the causes of various potato troubles in Europe, and **M. populi** Del.[28] is said to be the cause of canker on Populus.

Bacteriaceæ (p. 18)

Bacterium Ehrenberg (p. 18)

These non-motile forms, perhaps owing to their lack of power of locomotion, are comparatively rare as plant pathogens.

Bact. briosianum Pav. is given as the cause of rotting of tomato fruit and distortion of vegetative parts in Italy.[190] It is described also on Vanilla.[210]

Bact. montemartinii Pav. is described as the cause of a canker of Wisteria.[192]

Bact. mori B. & L. is said to cause leaf and branch spots on mulberry.[191]

Bact. teutlium Metcalf.[29] (Group number 222.—220—.)

A short rod with rounded ends, 1.5 x 0.8 μ, before division 3 x 1 μ; non-motile, no flagella seen; no spores; Gram-positive; agar colonies round, thin, not viscid, porcelaneous to transparent, seldom over 0.5 μ. No liquefaction. Broth clouded, precipitate thin or none, no pellicle. Milk not coagulated. T. D. P. 45°, 10 min. Opt. 17°. Aërobic, no gas.

Beets diseased by this organism were honeycombed with pockets filled with a viscous fluid, a practically pure bacterial culture. The vascular tissue was not rotted. Inoculation by pricking the bacterial exudate into healthy beets resulted in typical disease. Pure cultures isolated by use of cane-sugar-agar gave similar results. Three weeks after inoculation the exudate-forming pockets were typically developed. Surface inoculation failed and there is no evidence that the organism can infect except through wounds. No rotting followed inoculation on potato, white turnip, radish, tomato, or apple.

Bact. pini Vuill.[30] was found in tissue of pine galls and regarded as their cause.

Bact. fici Cav.[194] is reported as the cause of a disease of figs.

Bact. scabigenum Busse & v. Faber is described as the cause of scab of sugar-beets in Germany.[31]

Pseudomonas Migula (p. 18)

Short or long rods motile by polar flagella, fig. 10, whose number varies from one to ten but is most commonly one. Endospores are sometimes present. The cells in some species adhere to form short chains. The basis of separation into species is the growth upon gelatine, character of the colonies, chromogenesis and numerous other cultural characters.[32, 33, 34]

Something over seventy-nine species are known, at least fifteen of which cause diseases in plants, some of them very serious. Many other species occur in water, soil and manure, while others are suspected animal pathogens.

One prominent group of plant pathogens,[34] the yellow Pseudomonas group, contains, according to Smith, Ps. campestris, Ps. phaseoli, Ps. hyacinthi, Ps. stewarti, Ps. juglandis, Ps. vascularum, Ps. dianthi, Ps. amaranti, Ps. malvacearum. These, he says,

agree in the following particulars: They are yellow rod-shaped organisms of medium size, straight or slightly crooked with rounded ends. The segments multiply by fission, after elongation. They are generally less than 1 μ in diameter. The segments occur singly, in pairs or in fours joined end to end, or in clumpy masses of variable size (zoöglœæ), more rarely they are united into long chains or into filaments in which no septa are visible. Endospores have not been observed. The segments are motile by means of one polar flagellum which is generally several times as long as the rod, and may be wavy or straight when stained. The species grow readily on all of the ordinary culture media, but so far as is definitely known all are strictly aërobic. None are gas producers. They do not reduce nitrates to nitrites. The yellow color appears to be a lipochrome and in the different species varies from deep orange and buff-yellow, through pure chrome and canary-yellow, to primrose-yellow and paler tints.

Ps. æruginosus Del. possibly identical with **Ps. flourescens-putridus** Flügge is the cause of a leaf and stem disease of tobacco in France.[47]

Ps. avenæ Manns, (Group number 111.2223032.) A short rod with round ends, 0.5 to 1 μ x 1 to 2 μ. Actively motile, generally by one polar flagellum, occasionally by two or three. Gram negative. What seem to be endospores are found in old cultures. On agar stroke, growth very slow, filiform, rather flat, glistening; margin smooth, opaque to opalescent; non-chromogenic. Liquefaction occurs on gelatine in seven to twelve days. Broth is slowly clouded. Agar colonies, amorphous, round with surface smooth, edges entire. No gas in dextrose, saccharose, lactose, maltose, or glycerine. Ammonia and indol not formed. Nitrates reduced to nitrites. T. D. P. 10 min., 60°, Opt. 20° to 30°.

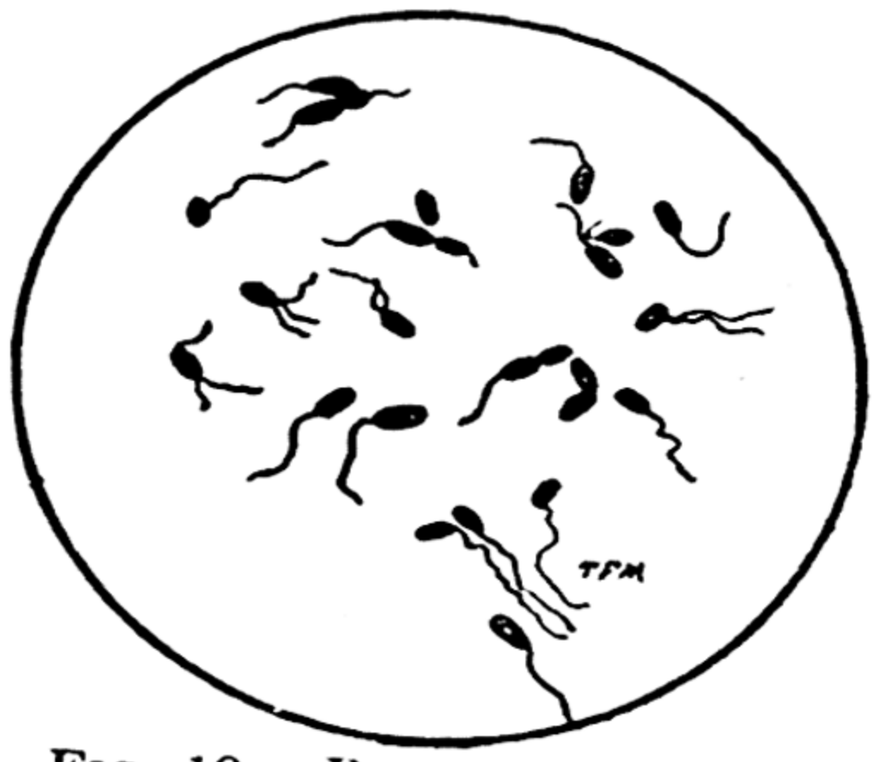


FIG. 10.—Ps. avenæ. After Manns.

This organism was isolated and described by Manns in 1909,[35] as the cause of a serious oat blight. Inoculations with it alone by

hypodermic injection produced only limited lesions but similar inoculations with a mixed culture of Ps. avenæ and Bacillus avenæ produced typical disease. Manns, moreover, noticed that the virulence of the Pseudomonas decreased when kept in culture free from the Bacillus, also that in the disease as it occurs in nature these two organisms are associated. His conclusion is that the Pseudomonas is the active parasite and that the Bacillus is an important, perhaps a necessary symbiont.

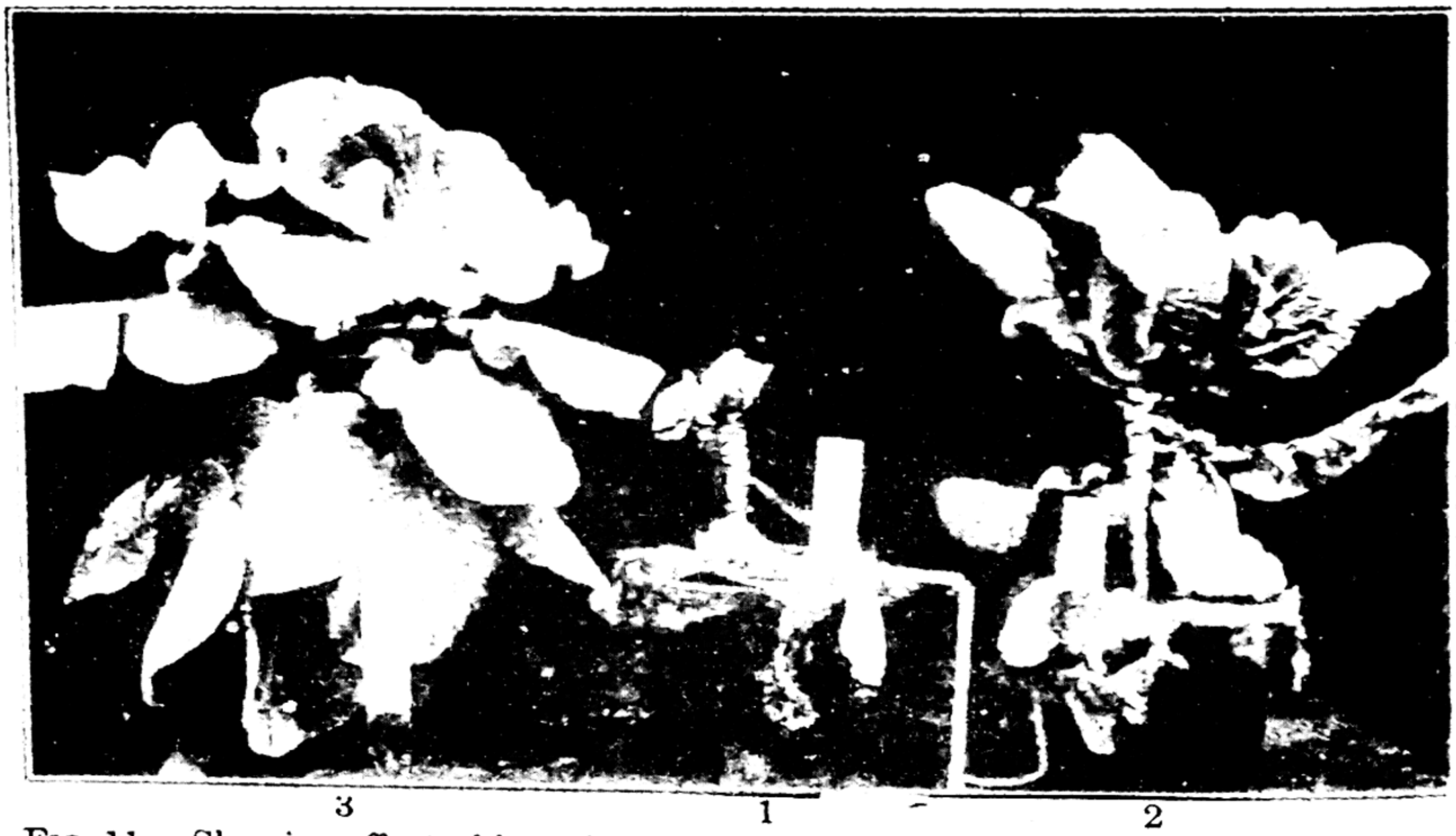


FIG. 11.—Showing effect of inoculation of Ps. campestris into cabbage plants. Nos. 1 and 2, six weeks after inoculation. No. 3, check plant uninoculated. After Russell.

Infection in nature is chiefly stomatal by spattering rain. Soaking of seed in suspensions of bacteria did not produce the disease. Inoculations on wheat failed, though from one variety of blighted wheat, Extra Square Head, the typical organism was isolated. Inoculations on corn made during wet weather produced lesions which spread rapidly and the organism was re-isolated. Barley is said by Manns to be susceptible and what he believes to be the same disease occurs on blue grass and timothy.

Ps. campestris (Pam.) E. F. Sm. (Group number 211.333151.) A rod-shaped, motile, organism generally 0.7 to 3.0 x 0.4 to 0.5 μ; color dull waxy-yellow to canary-yellow, occasionally brighter or more pale. One polar flagellum; no spores known. Aërobic but

not a gas or acid producer, gelatine liquefied. Cavities are formed around the bundles but the organism seems to be only feebly destructive to cellulose. A brown pigment is produced in the host plants and on steamed cruciferous substrata. Growth rapid on steamed potato cylinders at room temperatures, without odor or brown pigment. Growth feeble at 7°, rapid at 17 to 19°, luxuriant at 21 to 26°, very feeble at 37 to 38° and ceases at 40°. T. D. P., 10 min., 51°.

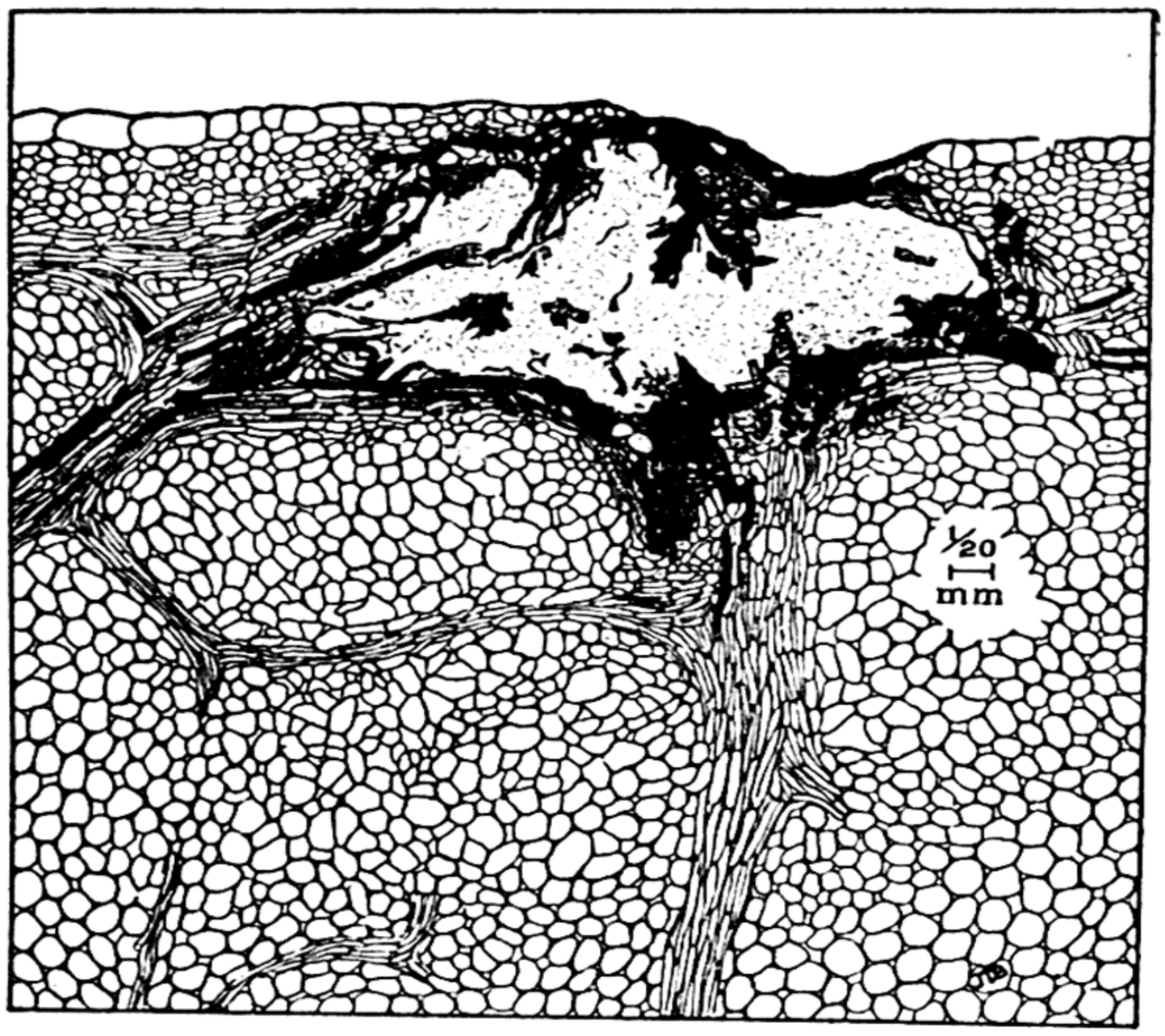


FIG. 12.—Ps. campestris. Section of a cabbage leaf parallel to the surface and near the margin, showing the result of infection through the water-pores. After Smith.

It is closely related to Ps. hyacinthi from which it differs chiefly in its pathogenic properties, its duller yellow color and its higher thermal death point. It is troublesome upon cabbage, turnips, cauliflowers, collards; and a very large number of cruciferous hosts, both cultivated and wild are susceptible. It enters the host plant through the vascular system which becomes decidedly brown.

This organism was first isolated by Pammel [36] (see also [41]) from rutabagas and yellow turnips in 1892; green-house inoculations with pure cultures were made in scalpel wounds, which were then

sealed with wax. The plants showed rot in a few days and the actual causal relation of the organism was thus established. Confirmatory evidence was gained by Russell [37] from puncture inoculations in cabbage and cauliflower petioles. It was further shown by E. F. Smith [38] that the cabbage and turnip organisms are identical and that the bacteria, by solution of the cellulose, produce pits and holes through the walls of the host cells resulting eventually in large cavities.

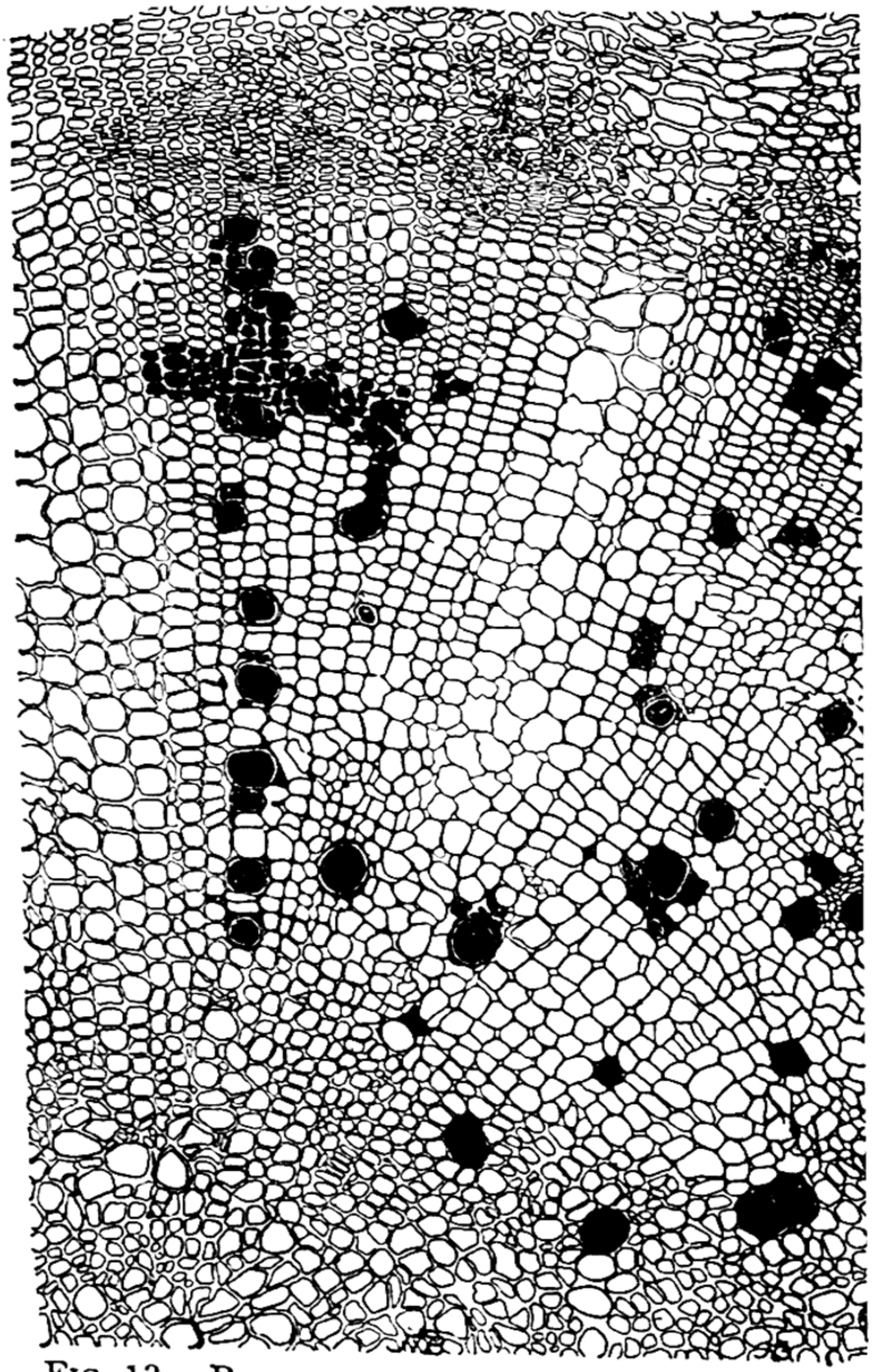


FIG. 13.—Ps. campestr s; cross-section of a turnip root. After Smith.

Infection was shown by Russell [37] and by Smith [38, 39] to be chiefly through the water pores or through wounds made by insects; the bacteria being air or insect borne and derived largely from infected soil. After entering the plant the bacteria multiply rapidly, and migrate in every direction by means of the veins.

Studies of Harding, Stewart and Prucha [40] (see also) [42] showed that it can survive the winter on the seed and thus infect seedlings.

Ps. destructans Potter [43] is described as an uniflagellate organism causing a destructive soft rot of turnips and beets in England. Doubt has been thrown upon its identity by the work of Harding and Morse [33] and of Jones [44] who found supposedly authentic cultures to bear peretrichiate rather than polar flagella. See p. 42.

Ps. dianthi Arth. & Boll.[45] Though originally reported as the probable cause of carnation leaf spot, this organism is now regarded as a saprophyte.

Ps. fluorescens (Flügge) Mig. Straight and curved rods of medium size in chains of two or several members. Cells 0.68 x 1.17–1.86 μ. Spores not seen. Flagella 3–6 polar.

Gelatine liquefied; surrounding medium colored greenish-yellow; Gram negative. Milk not coagulated. Indol weak. Bouillon, turbid, fluorescent.

This organism or two varieties of it are by Barlow [46] held responsible for a decay of celery. The organism was found in large numbers in the decayed tissue; was isolated and typical rot was induced by inoculation of pure cultures upon sterilized celery stems.

It is also credited with two distinct types of tobacco disease in France, one of them on seed, the other on the growing plant. Recently Griffon [47] has claimed that both of the varieties, Ps. fluorescens liquefaciens and Ps. putrida are capable of producing wet rot of various vegetables, carrots, rutabagas, tobacco, tomatoes, melons, and that the latter organism is identical with Ps. æruginosus. It is also held that B. brassicævorus and B. caulivorus are forms of Ps. fluorescens.

Ps. fluorescens exitiosus v. Hall is said by van Hall [50] to cause rot of Iris.

Ps. hyacinthi (Wak.) E. F. Sm., is a serious pest of hyacinths in the Netherlands but has not yet been recorded in America.[49] It is medium sized rod with rounded ends, measuring in the host 0.8–1.2 x 0.4–0.6 μ; actively motile by one long polar flagellum; non sporiferous; liquefies gelatine slowly; aërobic; no gas. It produces indol. Does not grow at 37°. Opt. 28 to 30°, T. D. P. 10 min., 47.5°. It is a wound parasite which grows in the vessels forming a bright yellow slime and is closely related to Ps. campestris and Ps. phaseoli.



FIG. 14.—Ps. hyacinthi. After Smith.

Ps. iridis v. Hall [50] is described by van Hall as the cause of decay of shoots and rhizomes of Iris.

Ps. juglandis Pierce. (Group number –11.——51–.) [51] A rod

1–2 x 0.5 μ, with rounded ends, actively motile by one long polar flagellum. Bright chrome-yellow in growth; disastatic ferment present. No gas; aërobic. It was isolated from diseased nuts, leaves, and twigs of English walnut in California in 1901. Inoculations by spraying demonstrated its pathogenicity. The organism is closely related to Ps. campestris but is distinguished from it by the abundant bright yellow pigment produced upon the surface of extracts of leaves of walnut, magnolia, fig, castor bean and loquat.

Ps. leguminiperdus (v. Oven.) Stev.,[52] said to be distinct from Ps. phaseoli, occurs on peas and other legumes. It was isolated, cultivated and inoculations made.

Ps. levistici Osterw.[53] occurs on Levisticum.

Ps. maculicolum (McC.) Stev. (Group number 211.3332023.) A short rod, forming long chains in some media. Ends rounded. Size from leaf 1.5 to 2.4 μ by 0.8 to 0.9 μ; in 24-hour beef-agar culture, 1.5 to 3 μ by 0.9 μ. No spores, actively motile, one to five polar flagella two to three times the length of the rod. Motile in most artificial media. Involution forms in alkaline beef bouillon. Pseudo-zoöglœæ in Uschinsky's solution. Gram negative. Stains readily with carbol fuchsin and with an alcoholic solution of gentian violet.

Agar plate colonies visible on the second day as tiny white specks, in three to four days, 1 to 3 mm. in diameter, white, round, smooth, flat, shining, and translucent, edges entire, with age dull to dirty white, slightly irregular, edges undulate, slightly crinkled, and with indistinct radiating marginal lines. Buried colonies small, lens-shaped.

Agar streak cultures white, margins slightly undulate. Beef bouillon clouds in twenty-four hours. Growth best at surface where a white layer, not a true pellicle, is formed. No zoöglœæ. No rim.

Gelatine stab cultures liquefied in eight to ten days. Growth from surface crateriform; slight, white, granular precipitate. Slight green fluorescence. No separation into curd and whey. Indol production feeble. T. D. P. 46°. Opt. 24–25°. Max. 29°. Min. below 0°.

Isolated from cauliflower leaves on which it forms brownish to

purplish-gray spots 1–3 mm. in diameter.[204] Pathogenicity on this host also on cabbage was proved by inoculation. Its entrance is stomatal.

Ps. malvacearum, E. F. Sm.[34, 39, 205] This yellow organism, pathogenic on cotton, much resembles Ps. campestris but its slime is more translucent on potato and it does not attack the cabbage. It was grown in pure culture by Smith and successful inoculations were made by spraying a suspension of a young agar culture of the organism upon cotton leaves and bolls. No description has been published.

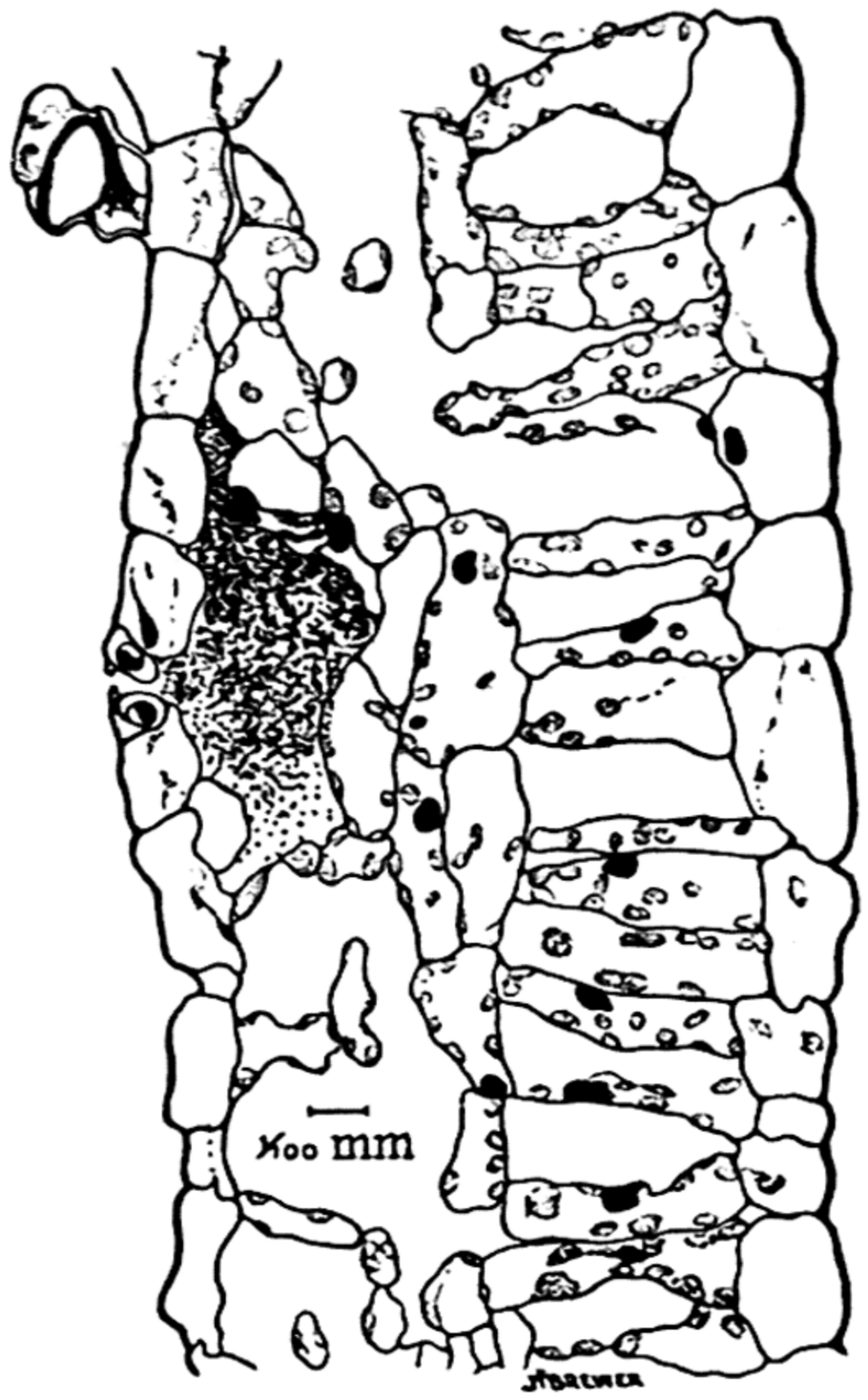


FIG. 15.—Ps. malvacearum. Early stage of stomatal infection in angular leaf-spot of cotton. After Smith.

Ps. medicaginis Sackett.[54] (Group number 212.3332133.) A short rod, 1.2–2.4 x 0.5–0.8 μ; filaments 20.2–37.2 μ long. No spores; actively motile with 1–4 bipolar flagella; capsules and zoöglœa none. Agar streak filiform, later echinulate, glistening, smooth, translucent, grayish-white; no gelatine liquefaction; bouillon slightly turbid, pellicle on third day, sediment scant. Milk unchanged. Agar colonies round, grayish-white. No gas or indol. Optimum reaction +15 to +18 Fuller's scale. T. D. P. 49–50°, 10 min. Opt. 28–30°. Aërobic. No diastase, invertase, zymase, rennit or pepsin.

It occurs as a pathogen on alfalfa and issues in clouds visible to the naked eye from small pieces of tissue of the diseased stem or leaf when mounted in water on the slide. These clouds under the high power resolve into actively motile rods, relatively short and thick. The bacteria are also found in practically pure culture in the exudate which oozes from the diseased tissue as a clear viscous liquid and collects in drops or spreads over the stem. Sackett with pure culture inoculations produced the typical disease and re-isolated the organism with unchanged characters. Re-inoculated

it again caused disease. More than a hundred inoculations by scarification or puncture gave one hundred per cent infection. Controls remained undiseased. Infection, stomatal or water pore, was also secured through the apparently unbroken epidermis. The virulence of the organism was retained after five months on agar. It is believed that the usual mode of infection is through rifts in the epidermis due to frost and that the germ is wind-borne from infected soil.



FIG. 16.—Ps. medicaginis; 48-hour agar-culture, showing formation of filaments. After Sackett.

Ps. michiganense (E. F. Sm.) Stev. (Group number –22.——252–.) Rod short with rounded ends, 0.35–0.4 x 0.8–1.0 μ. No motility seen from stems. Flagella apparently polar but not seen distinctly. Agar colonies pale-yellow, smooth, round. Agar stab canary-yellow, opaque, viscid. Bouillon moderately clouded, a moderate slimy precipitate; no rim or pellicle. Gelatine not liquefied.

The organism was described by Smith [55] as the cause of a stem disease of tomatoes in Michigan. No fungi were seen but bacteria were present in great numbers in the bundles also in cavities in the pith and bark. The organism was isolated and the disease was produced both by pure culture inoculations and by crude inoculations, using an impure inoculum. The disease caused is less rapid in development than that caused by B. solanacearum and less browning of the infected tissue occurs.

Ps. mori (B. & L.) Stev. (Group number 222.——202–.) Rod with rounded ends, 1.8–4.5 x 0.9–1.3 μ, mostly 3.6 x 1.–2 μ; motile by one, sometimes two polar flagella. No spores. Pseudozoöglœæ present. Agar colonies round, smooth, flat. Agar streaks spreading, flat, dull-white. Gelatine stab filiform, no liquefaction. Milk not coagulated. No gas. T. D. P. 51.5°.

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In 1894 Boyer and Lambert [56] produced successful inoculations on mulberries with an organism to which they gave the above name, but without description.

In 1908 E. F. Smith,[57] plated out, from blighted mulberry leaves collected in Georgia, a white species with which he made numerous infections on both stems and leaves of mulberry. From these cultures Smith supplied the description quoted in part above. The relation which **Bacillus cubonianus** [58] has to this mulberry disease is unknown.

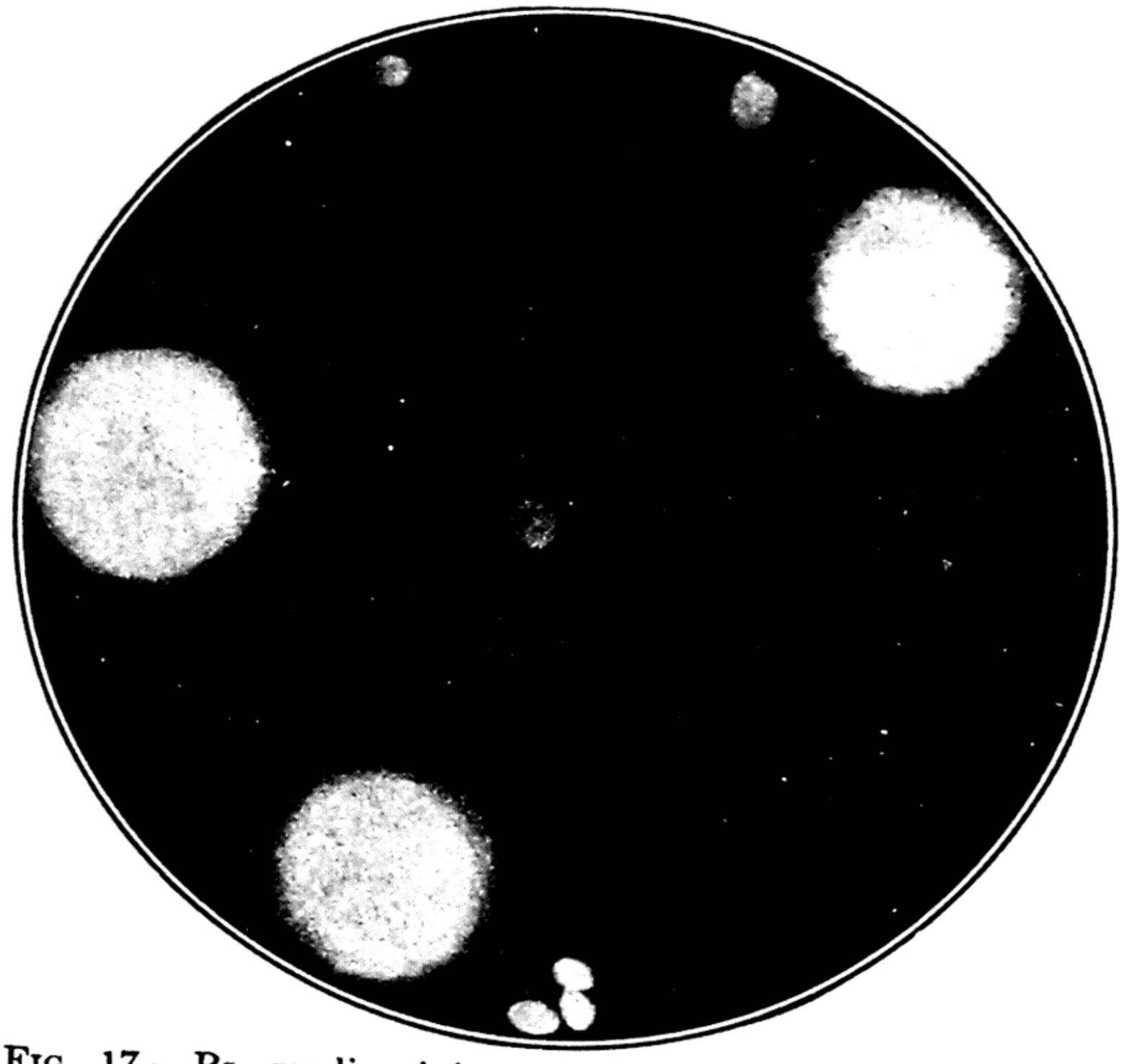


FIG. 17.—Ps. medicaginis; agar colonies 7 days old, deep aud surface colonies by reflected light. After Sackett.

Ps. phaseoli E. F. Sm. A short round-ended rod, wax-yellow to chrome; motile; anaërobic. Milk coagulates, and the whey slowly separates without acidity; gelatine liquefies slowly. Growth feeble at 37°, none at 40°. T. D. P. 10 min., 49.5°. A starch enzyme is produced and the middle lamella also dissolved.



FIG. 18.—Ps. phaseoli. After Smith.

This organism is pathogenic to beans and some related legumes and is closely related to Ps. hyacinthi and Ps. campestris. The bean disease, occasioned by it was noted and ascribed to bacteria by Beach [59] and by Halsted [60] in 1892, and the organism was described by E. F. Smith in 1897 [61] after it had been grown in pure culture and successful inoculations had been made.

Ps. pruni, E. F. Sm. The organism resembles Ps. campestris but is distinguished from it by its feebler growth on potato and by its behavior in Uschnisky's solution which it converts into a viscid fluid. It consists of small rods, motile by one to several polar flagella. T. D. P. 51°. Gelatine not liquefied. Casein slowly precipitated and later redissolved. No gas.

The bacteria enter through the stomata of the Japanese plum; [62] cause small watery spots on green fruit and leaves, and finally the

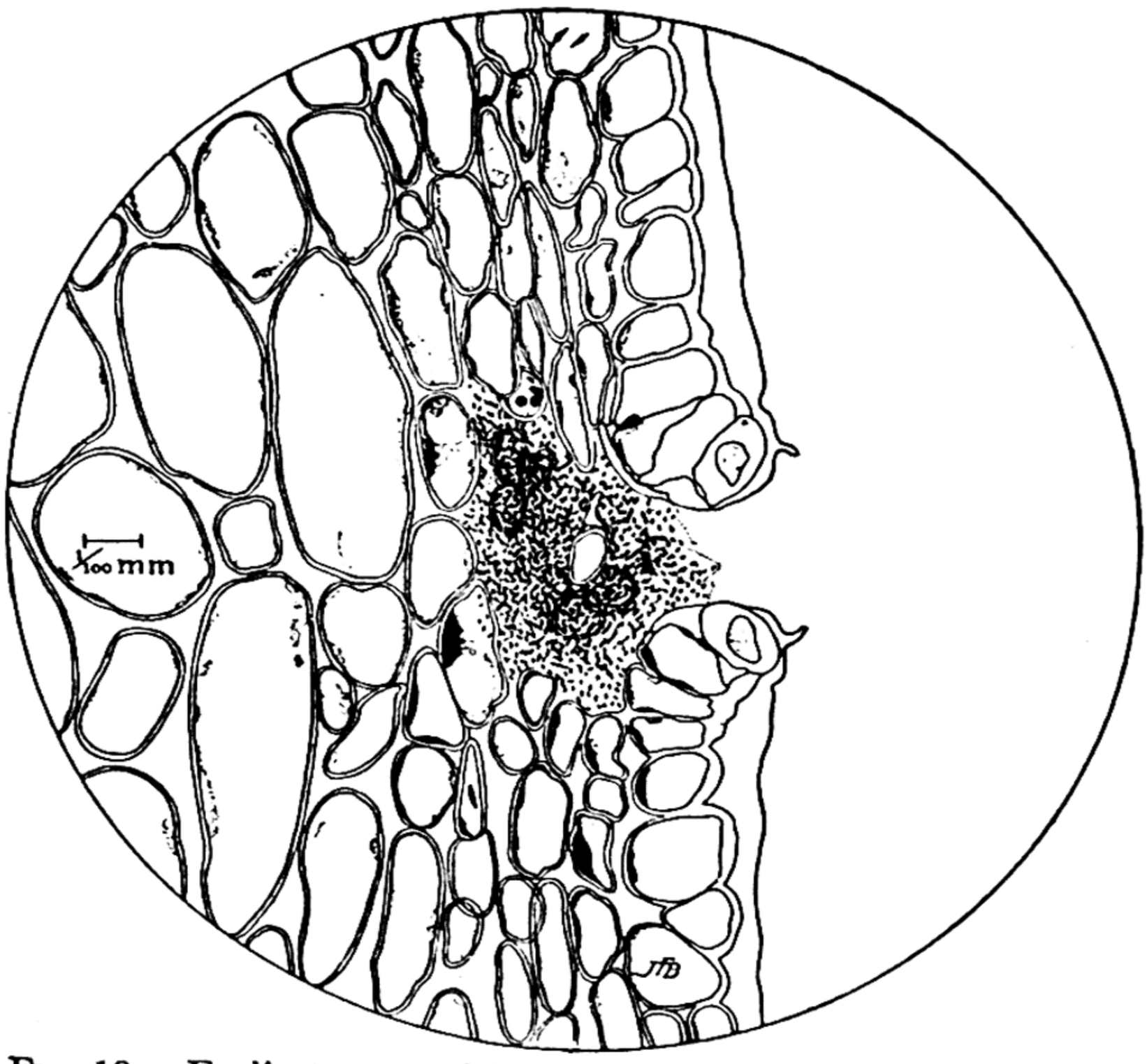


FIG. 19.—Earliest stage of fruit spot on green plums, due to Ps. pruni. The bacteria entered through the stoma. After Smith.

death of the affected tissue. In earliest disease they are limited to the substomatal space but gradually they invade more distant tissue. Wounds are not necessary to infection. It seems to have been seen first on the peach in 1903 by O'Gara in Georgia and in the same year by Clinton in Connecticut. Rorer [63] by numerous cultures and cross inoculations proved this same organism responsible for a leaf, twig and fruit disease of peaches. In the twig the bacteria were present in great numbers in the bast.

Ps. radicicola (Bey.) Moore.[64] The legume root-tubercle or-

ganism, by some regarded as a parasite, though beneficial, and by others regarded as a mutualistic symbiont will not be discussed here owing to its beneficial character.

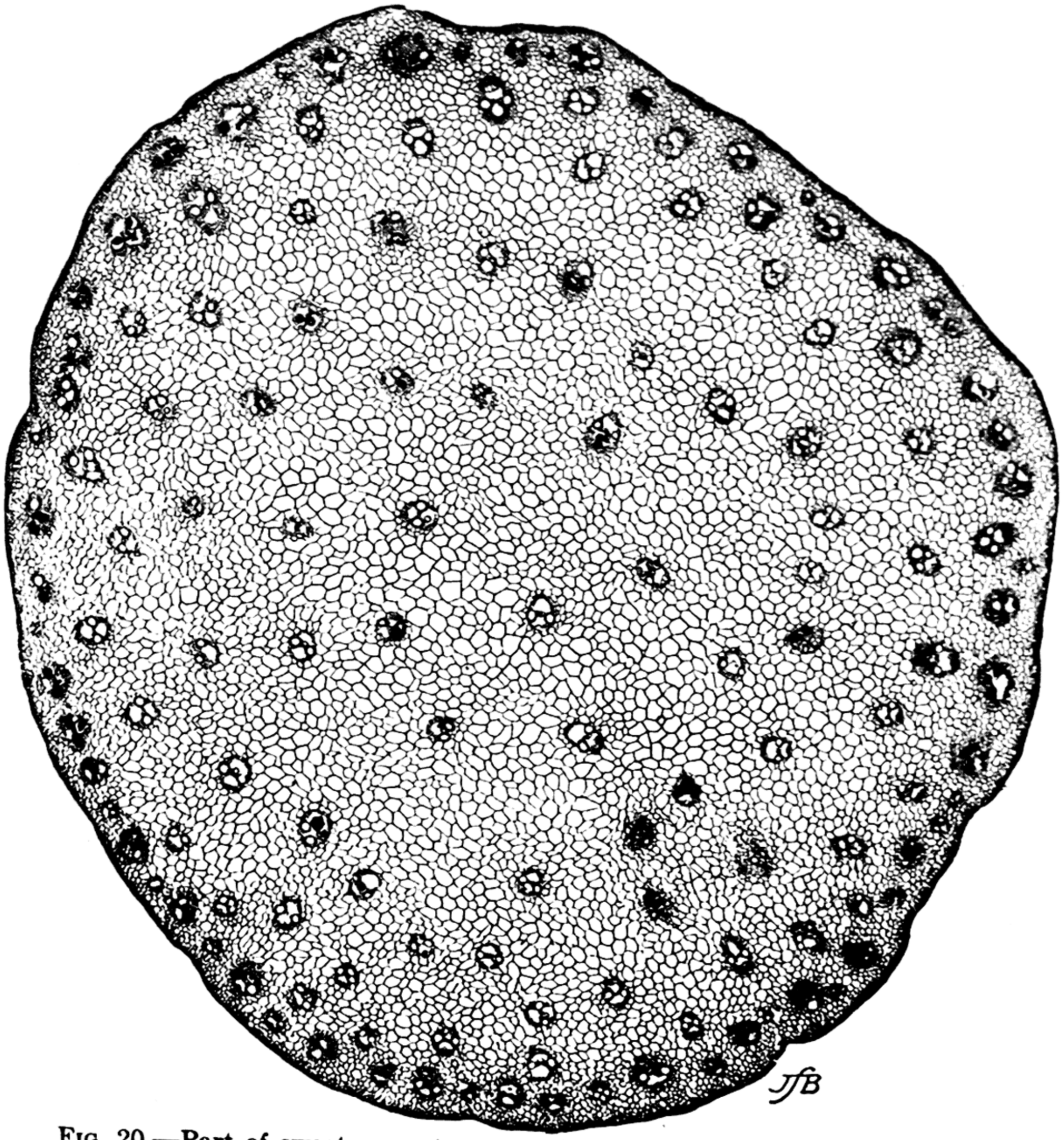


FIG. 20.—Part of sweet-corn stem parasitized by Ps. stewarti. After Smith.

Ps. savastanoi (E. F. Sm.) Stev. A rod with rounded ends, solitary or in short chains, 1.2–3 x 0.4–0.8 μ; motile; aërobic; non-sporing; flagella 1–several, often 2–4, polar. Standard agar, surface colonies, white, small, circular, smooth 1.5–3 mm. at three days, edge entire; bouillon thinly clouded, precipitate slight, white, no rim or pellicle. On gelatine no liquefaction; colonies white, round, erose, margin pale.

From swellings known as olive tubercles on Californian olive branches, E. F. Smith isolated this organism [65] which is in part Ps. oleæ-tuberculosis and which may bear relation to several other olive bacteria previously described in Europe.

The organism when inoculated by puncture into young olive shoots produced the characteristic tubercle. Later it was re-isolated from these artificially produced tubercles and used in a second series of inoculations which gave a second crop of tubercles. Controls showed no infection and healed promptly. The oleander was not susceptible to infection.

Smith's results are not in full accord with much of the European work on the olive tubercle.

Ps. sesami Malk. causes disease on sesame [66].

Ps. stewarti, E. F. Sm. A medium size rod, 0.5 – 0.9 μ x 1 – 2 μ, with rounded ends, and 1 polar flagellum. Buff-yellow to chrome or ochre color; non-liquefying; does not separate casein in milk. T. D. P. 10 min., 53°. Agar colonies subcircular, becoming lobate; bouillon rendered turbid with yellow-white precipitate. No gas.

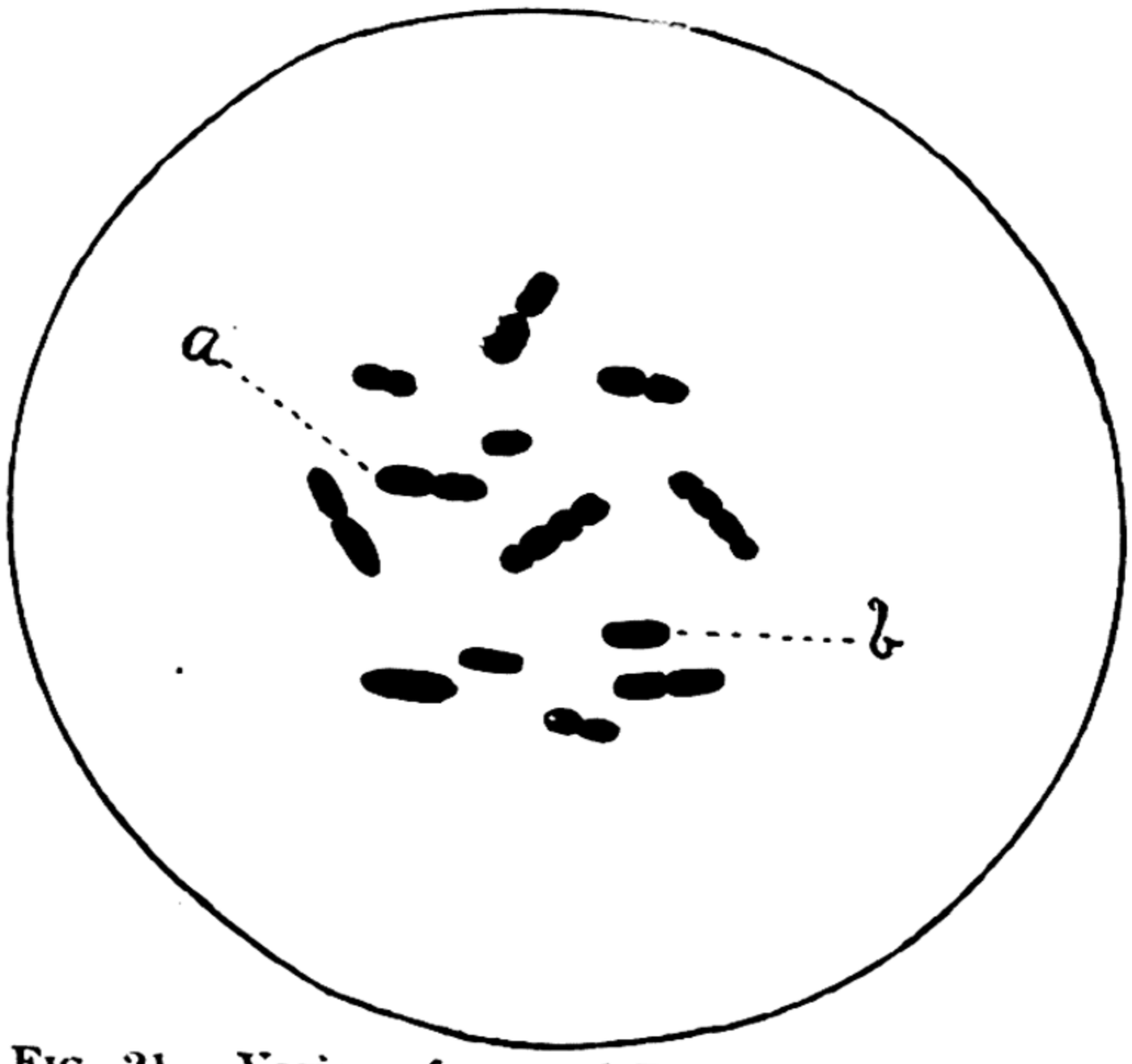


FIG. 21.—Various forms of Ps. stewarti, grown on potato agar; a and b are typical forms. After Stewart.

The bacterial corn blight of this organism was first described by Stewart in 1897 [67] and attributed to bacteria. The organism was described by E. F. Smith in 1890 [68] from a culture furnished by Stewart. Definite proof by inoculation of the causal relation of this particular organism to the disease was adduced in 1902 by sprinkling bacteria upon the leaves.[69, 70] Some plants showed typical constitutional symptoms during the first month, most of them in two or three months when the plants were several feet

high. In these plants the vessels become plugged with pure cultures of Ps. stewarti from tip to base. Small holes filled with yellow slime appeared later in the parenchyma. Wounds were entirely unnecessary to infection, though the vessels are the primary seat of disease.

Ps. syringæ v. Hall [71] causes disease of Syringa and other plants.

Ps. tumefaciens (S. & T.) Stev.[72-76] (Group number 212.2322023.) Vegetative cells taken directly from a gall usually 0.6 to 1.0 μ x 1.2 to 1.5 μ.

When grown on agar for two days 2.5 to 3 μ x 0.7 to 0.8 μ or occasionally wider. Endospores not observed. Motile by means of one, sometimes two or three terminal flagella; viscid on agar but capsules not demonstrated. Readily stained in ordinary basic anilin stains; Gram negative. Agar surface colonies usually come up in from four to six days at 25°, white, smooth, circular; margin even, shining, semi-transparent, maximum size 2 to 4 mm. Agar streak; growth moderate, filiform. On sterile potato cylinders growth more rapid, in one or two days covering the entire surface of the cylinder; smooth wet-glistening, slimy to viscid, odorless; potato cylinder grayish, darker with age, never yellow. Gelatine colonies dense, white, circular, small, non-liquefying, medium not stained. In beef broth clouding often absent or inconspicuous, rim of gelatinous threads present, also more or less of pellicle; in young cultures very delicate suspended short filaments, best seen on shaking. Milk coagulation delayed; extrusion of whey begins only after several days; litmus milk gradually blued, then reduced. Cohn's solution, growth scanty or absent, medium non-fluorescent.

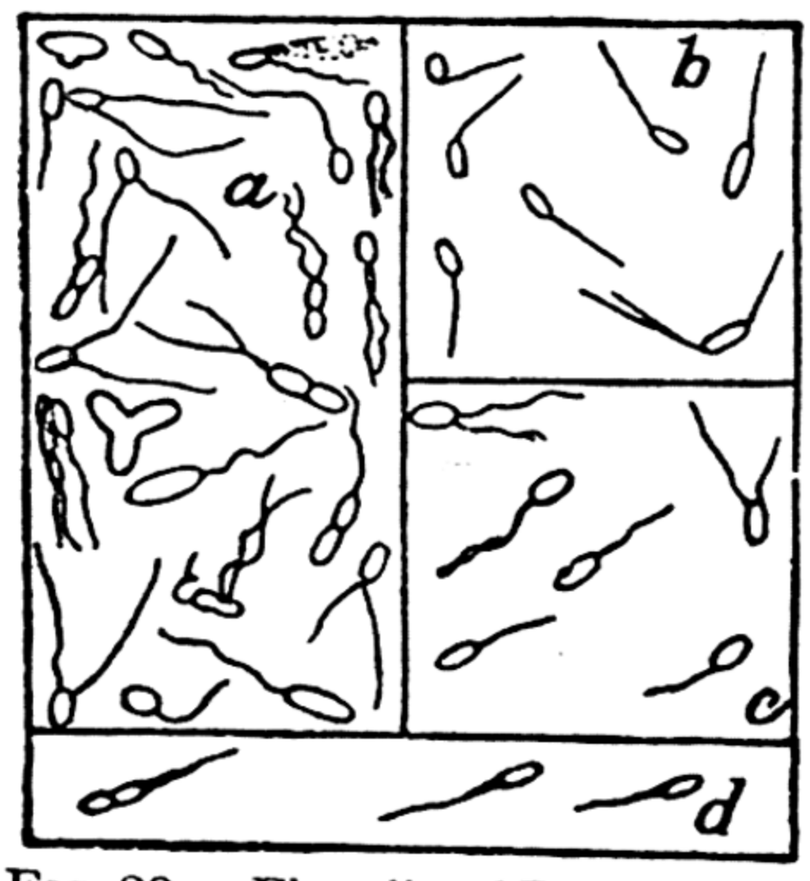


FIG. 22.—Flagella of Ps. tumefaciens, various stains. After Smith.

No gas produced; organism aërobic in its tendencies; nitrates not reduced. Indol produced in small quantity, slowly. Slight toleration for citric, malic, and acetic acids. Toleration for alkali slight. Optimum reaction between +12 and +24, Fuller's scale. T. D. P. 51°. Opt. between 25° and 28° Max. ±37° Growth

occurs at 0°. Milk, bouillon, dextrose peptone water with calcium carbonate are the best media for long continued growth.

The following are recommended as quick tests for differential purposes. Time of appearance of colonies on +15 agar plates made from the tumors; young agar stroke cultures; behavior in milk and litmus milk; growth on potato; behavior in Cohn's solution; stringy ring and suspended filaments in peptonized beef bouillon; inoculations into young, rapidly growing daisy shoots or into growing sugar-beet roots.

The organism is readily plated from young sound galls, i. e., those not fissured or decayed.

In galls on the Paris daisy (Chrysanthemum frutescens) these bacteria were found in small numbers. By plating they were obtained in pure culture and puncture inoculations repeatedly resulted in the characteristic gall. From these the organism was reisolated and the disease again produced, thus giving conclusive evidence that the organism is the actual cause of the gall. Swellings began four or five days after inoculation and in a month they were well developed though they continued to enlarge for several months, reaching a size of 2–5 cm. in diameter.

Tumor-producing Schizomycetes have also been isolated from over-growths on plants belonging to many widely separated families (Compositæ to Salicaceæ). Natural galls have been studied on Chrysanthemum, peach, apple, rose, quince, honeysuckle, Arbutus, cotton, poplar, chestnut, alfalfa, grape, hop, beet, salsify, turnip, parsnip, lettuce, and willow. The organisms from these sources are closely alike on various culture media, and many of them are readily cross-inoculable, e. g., **daisy** to peach, radish, grape, sugar-beet, hop; **peach** to daisy, apple, Pelargonium, sugar-beet, poplar; **hop** to daisy, tomato, sugar-beet; **grape** to almond, sugar-beet; **poplar** to cactus, oleander, sugar-beet; **willow** to daisy. With eight of these organisms tumors have been produced on sound specimens of the species from which obtained. Some cross-inoculate more readily than others, and there are also slight cultural differences. Thus, it is probable that there are several races of the gall-forming organisms varying more or less in amount of virulence and in adaptability to various hosts. In general it is said that all plants susceptible to crown galls, i. e.,

those on which the galls have been found in nature, are susceptible to artificial cross inoculation. Hard gall, hairy root, and soft gall are also all due to infectious bacteria.

As tentative hypotheses Smith assumes either: (1) That the hairy root organism while resembling the crown gall organism is not identical with it; or (2) That they are the same, and that if infection takes place in a certain group of cells an ordinary gall will develop, while if other special groups of cells are first invaded, i. e., the root anlage, then a cluster of the fleshy roots will develop. Some of his inoculation experiments point to the latter conclusion.

Ps. vascularum (Cobb) E. F. Sm. [77, 78, 58] is parasitic on sugar cane, filling the bundles with a yellow slime. It has not been reported in America.

Ps. sp. indet. A short rod, 2–4 x 1–1.5 μ, actively motile by 1–3 polar flagella, was isolated from diseased spots on the larger veins and petioles of beet leaves by Brown.[79] The organism was successfully inoculated in pure culture, disease produced, and the organism reisolated. It is infective as well for lettuce, sweet pepper, nasturtium, egg plant and bean. Agar colonies are creamy white, thin, circular, turning the surrounding agar yellow-green in three days. Gelatine is liquefied; litmus milk turns blue; bouillon is clouded. Opt. 28°.

Ps. sp. indet. A short rod, 2–4 μ long, motile by 1–3 polar flagella was isolated from diseased nasturtiums (Tropeolum) leaves by Jamiesson.[80] Pure culture inoculations induced typical disease. The organism clouds bouillon; produces on agar small, round, bluish-white colonies; liquefies gelatine and does not produce gas. Opt. 25°. T. D. P. 49–50°, 10 min. It is pathogenic also for sweet-pea, lettuce, pepper, sugar-beet and bean.

Bacillus Cohn. (p. 18.)

This genus differs from Pseudomonas only in its peritrichiate, not polar, flagella. Endospores are often present. Of the four hundred and fifty or more species nineteen at least are known to be plant pathogens. Numerous animal pathogens also belong to this genus, notably B. typhosus, B. pestis.

B. ampelopsoræ Trev. is said to cause grape galls in Europe,[81] but the evidence is by no means conclusive. Cf. B. uvæ.

B. amylovorus (Burr.) De Toni. (Group number 221.——0—.)

Bacillus in broth, 0.9–1.5 x 0.7–1.0 μ, longer when older. Gram positive; no capsule; flagella several; no spores; broth clouded, pellicle slight. Gelatine shows slow, crateriform liquefaction. Agar, buried colonies white, surface colonies elevated, circular wet-shining, margin irregular. Milk coagulated in three-fourths of a day, later digested to a pasty condition. Opt. 25–30°. T. D. P. 43.7°, 10 min. Facultative anaërobe. Indol produced; no gas; no pigment.



FIG. 23.—B. amylovorus, multiplying by fission. After Whetzel and Stewart.

Bacteria were noted in blighted pear twigs by Burrill in 1877.[82, 83] In 1880 he [84] demonstrated the communicability of the disease by introducing the bacterial exudate into healthy pear trees as well as into apple and quince trees. This constitutes the first case of plant disease definitely attributed to bacteria. Burrill's results were confirmed by Arthur in 1884 [85] by one hundred and twenty-one puncture inoculations, using the exudate, also a bacterial suspension from diseased twigs. He further demonstrated the susceptibility of Juneberry and hawthorn. Usually the disease appeared about a week after inoculation. Attempted raspberry and grape inoculations failed.

Arthur placed the whole matter on a firm foundation by passing the bacteria through a long series of artificial cultures and then by inoculations, showing that they were capable of causing the blight.[86, 87] He further demonstrated that the bacterial exudate from the tree, when freed of bacteria by filtration, could not produce disease. The results of an extensive study of the bacteria on various media; of their morphology and stain reactions were published by Arthur in 1886.[88] Bacteria were shown to penetrate twigs 3–4 dm. beyond their area of visible effect.[207]



FIG. 24.—Claw from bee's foot with blight bacteria on and about it showing the relative size. After Whetzel and Stewart.

In 1902 Jones [89] isolated an organism from blighted plum trees.

This he demonstrated by culture and cross inoculation in fruits to be identical with the pear blight organism, though inoculations in plum twigs did not give disease, presumably due to the high resistance of this plant. Similarly Paddock has shown this organism to attack the apricot.[90] Detmers has reported what she regarded as this blight caused by this Bacillus on blackberries.[91]

Other hosts are hawthorn, shad bush, mountain ash.

By inoculations with pure cultures of the apple body-blight bacteria, blight upon twigs and blossoms was produced by Whetzel in 1906,[92] thus proving the identity of these two forms of disease, an identity asserted first by Burrill.[93]



FIG. 25.—B. aroideæ. After Townsend.

B. apii (Brizi.) Mig.[94] is reported as the cause of a celery rot, which is possibly identical with a bacterial rot reported earlier by Halsted.[95]

B. araliavorous Uyeda, described on Ginseng in Korea is perhaps also the cause of soft rot of Ginseng in America.[96] The organism was isolated and studied by Uyeda who made inoculations.

Pseudomonas araliæ and Bacillus koraiensis were also commonly present in the Oriental disease.[97]

B. aroideæ Town. (Group Number 221.2223022.) [33]

This organism was described in 1904 as the cause of soft rot of calla [98] corms and leaves. The bacteria were present in almost pure culture in affected tissue and by puncture inoculation in pure culture produced the typical disease in a few days.

Townsend regarded the organism as distinct from B. carotovorus, B. oleraceæ, B. hyacinthi septicus and Pseudomonas de-

structans. Harding and Morse, however, believe it specifically identical with B. carotovorus. See p. 42.

B. atrosepticus v. Hall,[99] was isolated from ducts of potatoes affected with black leg.

B. avenæ, Manns.[35] This is the symbiont of Pseudomonas avenæ. See p. 23.

(Group number 222.2223532.) A very actively motile bacillus, short, rod-shaped with rounded ends, 0.75 to 1 x 1.5 to 2 μ.

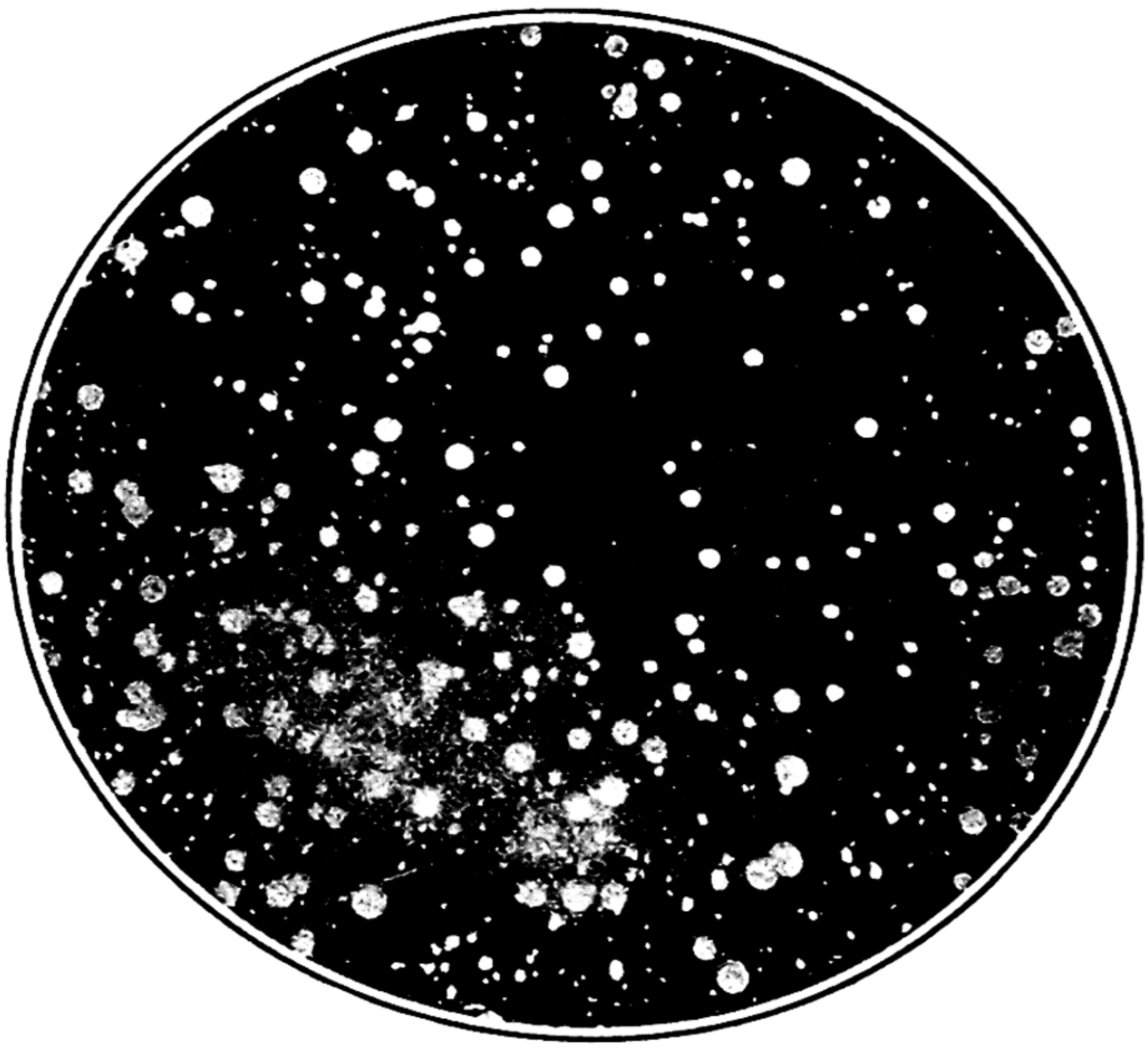


FIG. 26.—Plate culture of B. avenae, on nutrient glucose agar, four days at 30°C. After Manns.

Gram negative; endospores not observed; flagella many, diffuse, long, undulate; growth on agar stroke rapid, filiform, white, glistening, later somewhat dull, margin smooth, growth rather opaque, turning yellow third day; gelatine not liquefied; broth clouded and on the second day showing heavy yellow precipitate; milk coagulated at end of two weeks with extrusion of whey; agar colonies round, entire, surface smooth, slightly raised. No gas in dextrose, saccharose, lactose, maltose, or glycerins. Indol production moderate; nitrates reduced to nitrites. T. D. P. 10 min., 60°; Opt. 20–30°.

B. betæ Mig. is reported as the cause of gummosis of beet.[100]

B. brassicævorus Del. isolated from diseased cabbage [101] is perhaps identical with Pseudomonas fluorescens. See page 27.

B. carotovorus Jones. (Group number 221.1113022.) From agar 1–2 days old as short or long rods, in short or long chains. 0.7–1.0 x 1.5–5 μ, commonly 0.8 x 2 μ; ends rounded. No spore; flagella 2–10, peritrichiate; no capsule; Gram negative. White on all media. Agar slope filiform to spreading, glistening, opaque to opalescent. In gelatine stab; liquefaction crateriform to infundibuliform. Broth clouded, pellicle thin to absent, sediment flocculent; milk coagulated. Agar colonies, round, smooth, entire to undulate, amorphous or granular. Some gas in dextrose, lactose and saccharose, nitrates reduced to nitrites; indol feeble. T. D. P. 48–50°. Opt. 25–30°.

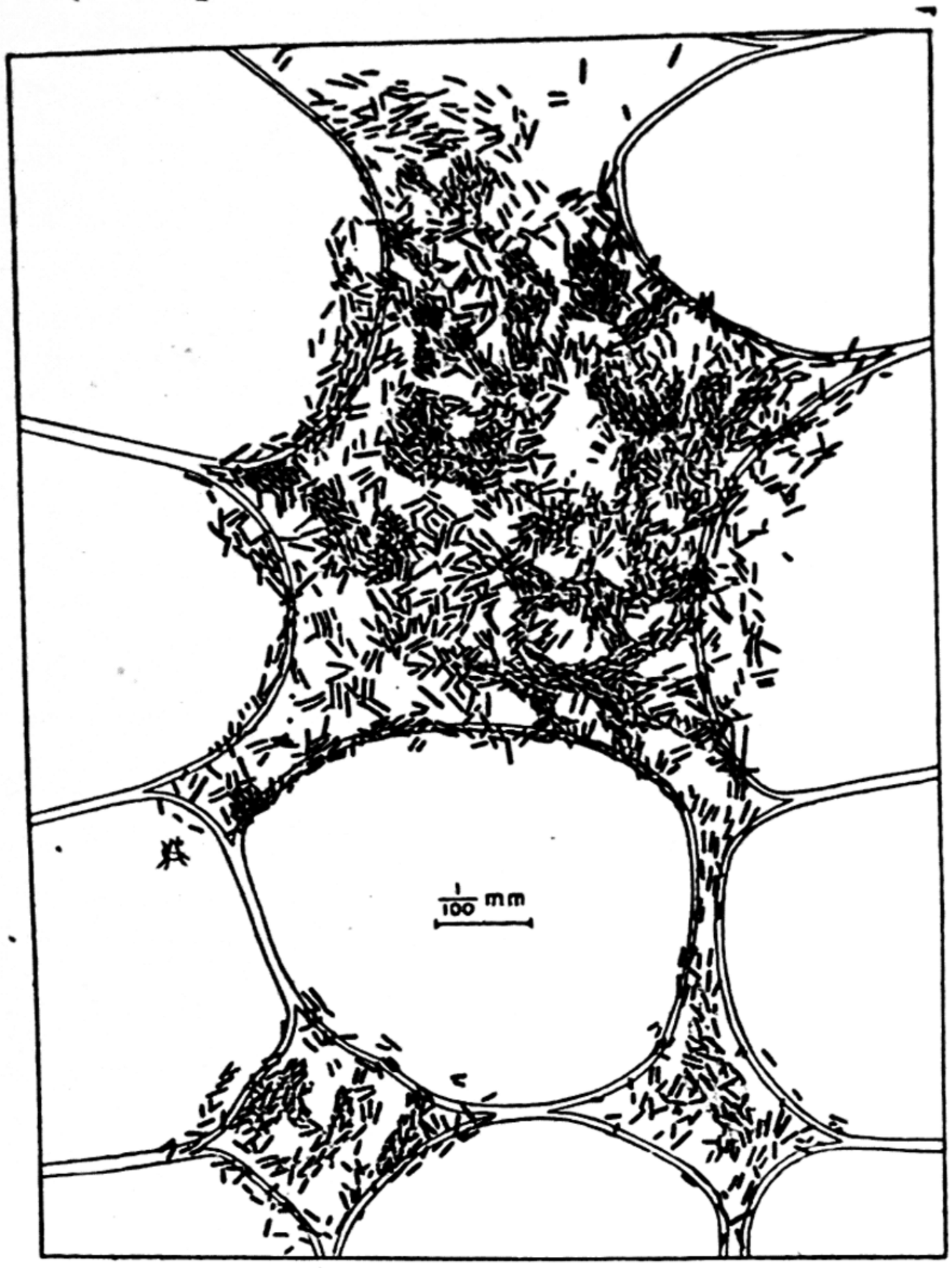


FIG. 27.—B. carotovorus wedging apart cells of the carrot. After Smith.

A considerable number of cultivated plants suffer soft rot from the attacks of a non-chromogenic liquefying bacillus. Among the plants so affected are cabbage, turnips and other crucifers; parsnip, carrot, mangel, sugar-beet, potato, celery, tomato, Jerusalem artichoke, asparagus, rhubarb, onion and iris.

In 1901, Jones reported an organism isolated from rotting carrots which he named B. carotovorus.[102, 103] It disorganized tissue by solution of the middle lamella; and infection into wounds led

to decay of roots of carrot, parsnip, turnip, radish, salsify, of onion bulbs, hyacinth corms, cabbage heads, celery stalks and fruits of tomato, pepper and egg plant. Jones found no decay produced in young carrot or parsnip plants, fruits of orange, banana, apple, pear, cauliflower head,* Irish potato tuber, beet root or tomato stems.[104] Infection did not occur unless the epidermis was broken. The rotten mass was always soft, wet, and exuded a liquid clouded with bacteria.

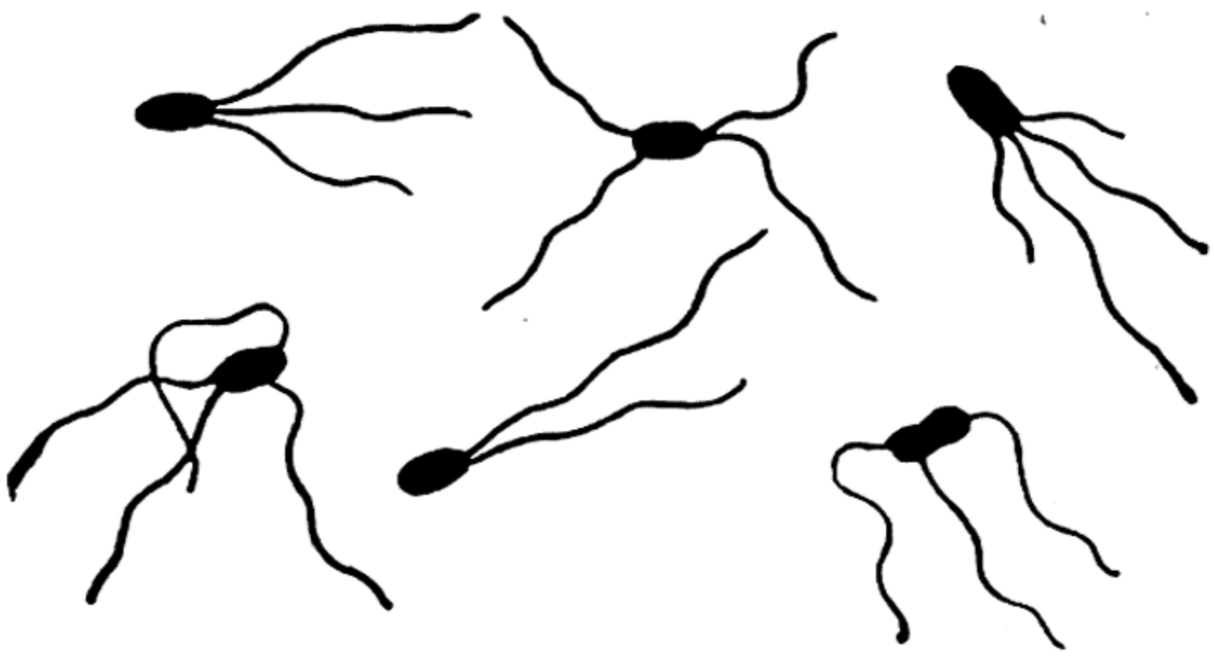


FIG. 28.—B. carotovorus. After Jones.

Jones [32] in 1909 made an extensive study of the cytolitic enzyme of this germ. This enzyme was separated by heat, filtration, formalin, phenol, thymol, chloroform, diffusion, alcohol, and its conditions of production and action investigated. Heating the enzyme to 60° inhibited its activity to a marked degree; higher than 63° inhibited it entirely; chloroform, thymol and phenol did not retard its action. No loss was suffered through alcoholic precipitation and resolution. The dried enzyme remained active for fully two years. Its effect was greatest at 42°, less at 32° and 48°. No diastatic action was observable.

In 1909 Harding and Morse,[33] from an extended study of some 12,000 cultures of non-chromogenic, liquefying soft-rot bacilli of some forty-three pathogenic strains (including B. carotovorus, B. oleraceæ, B. omnivorus, B. aroideæ and what Potter regarded as Pseudomonas destructans), from six different vegetables, conclude that unless later studies of the pathogenicity of these cultures shall offer a basis for subdividing them, there is no apparent reason why they should not all be considered as somewhat variant members of a single botanical species.

This conception would lead to the abandonment of the supposed species mentioned above and the recognition of all of them under their oldest described form, B. carotovorus Jones, which in our

* Harding and Stewart later showed that it is capable of rotting cauliflower.

present knowledge seems certainly to be the most wide spread, common and destructive of the soft rot bacteria. Some, perhaps much, of the rot of crucifers generally thought to be due to Pseudomonas campestris is probably caused by B. carotovorus. See Harding & Morse.[33]

B. caulivorus, Pril. & Del. has been reported as the cause of spots on grapes under glass,[24] also as a parasite on a large number of other plants among them Pelargonium, potato, begonia, clematis. It is later stated that this is probably really a variety of Ps. putrifaciens liquefaciens.

B. cepivorus Del. (possibly a Bacterium) is recorded on onion bulbs.[81]

B. coli (Esch.) Mig. or an organism indistinguishable from it is held by Johnston [189] capable of causing rot of soft tissues of the cocoanut plant and is perhaps responsible for cocoanut bud rot.

B. cubonianus Macc. was originally described as the cause of mulberry disease (cf. **Ps. mori**). This organism, or at least one that was regarded as indistinguishable from it, has been mentioned as the cause of a disease of hemp.[105]

B. cypripedii Hori is a medium sized slender, non-sporulating form with four flagella.[196]

B. delphini E. F. Sm. This is a motile, gray-white, nitrate-reducing, non-liquefying organism. On agar young colonies small, circular, wrinkled. Grows well at 30°, not at all at 37.5°. T. D. P. 48–49.1°.

The cause of stomatal infection of larkspur resulting in sunken black spots on leaves and stems.[106]

B. elegans Hegyi is reported on lupine.[107]

B. dahliæ Hori & Bakis is on dahlia.[198]

B. gossypini Stedman was reported by Stedman [108] as the cause of cotton-boll soft rot in Alabama; much doubt, however, remains as to its actual identity and causal relation. It was described as a short, straight, spore-forming motile bacillus; 1 .5 x .75 μ; aërobic; non-liquefying (?).

B. gummis Comes. has by some been held responsible for gummosis or *mal nero* of the grape vine [109] though others discredit this idea.

B. haria Hori & Miy. is a parasite of the Japanese basket willow.[197]

B. hyacinthi septicus Heinz,[110] is recorded as the cause of a soft white rot of the hyacinth.

B. lactucæ Vogl. is said to cause a lettuce disease.[111]

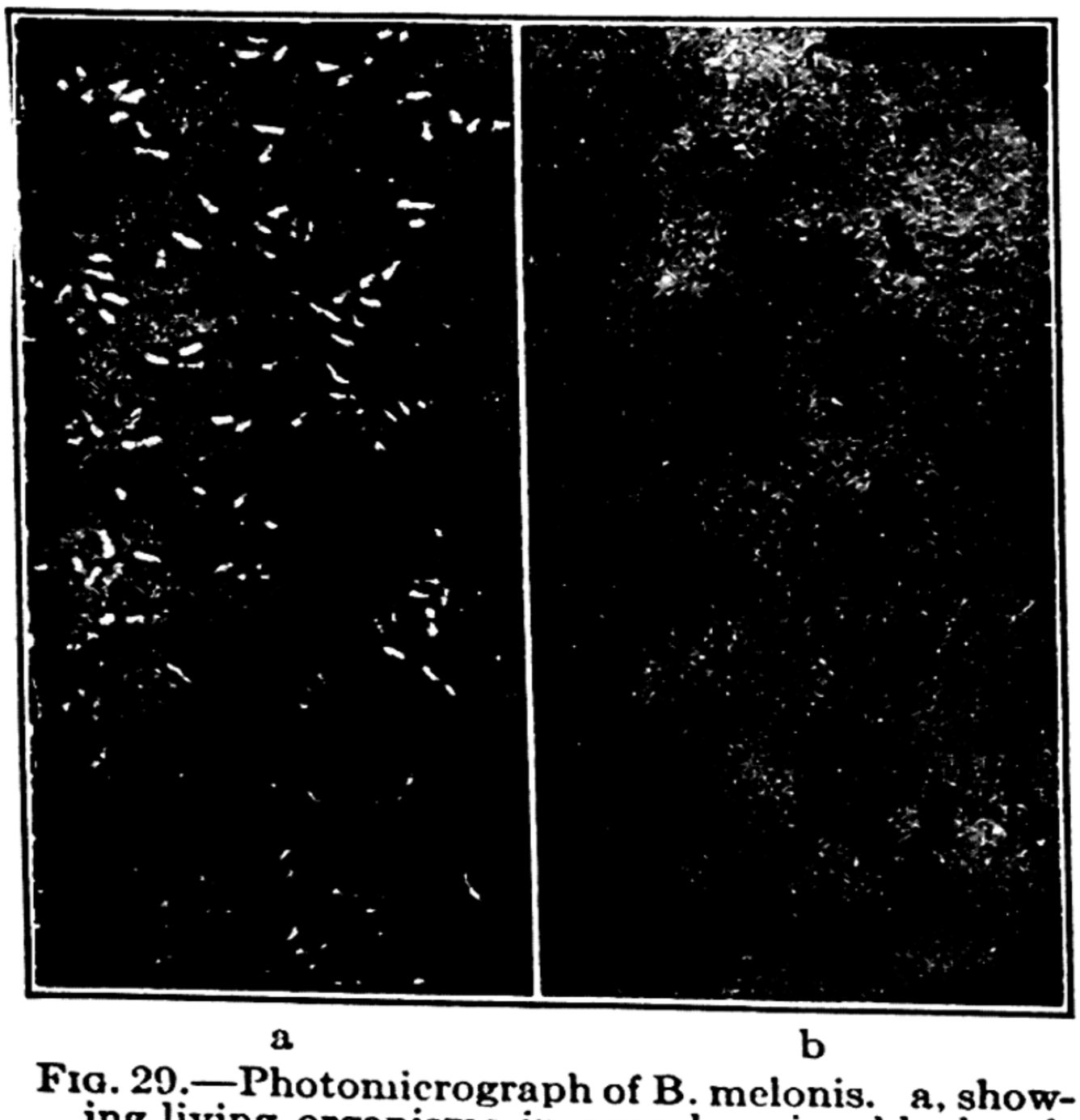
B. lycopersici Hegyi has been described as the cause of a rot of tomatoes.[112]

B. maculicola Del. is regarded as the cause of a tobacco leaf spot.[113]

B. melanogenus P. & M.[114] is recorded in England on potatoes.

B. melonis Giddings.[115]

An actively motile bacillus, 0.6–0.9 x 1–1.7 μ; flagella 4–6 peritrichiate; no spores. Gram negative. Broth strongly clouded, no pellicle or ring, slight sediment. Agar stroke slimy, glistening translucent; colonies round or amœboid. In gelatine stab liquefaction infundibuliform in two days. Milk coagulated with abundant gas. Nitrite production abundant; indol slight. T. D. P. 49–50°. Opt. 30°. The vegetables rotted were muskmelon, citron, carrot, potato, beet, cucumber and turnip.



a b

FIG. 29.—Photomicrograph of B. melonis. a, showing living organisms in agar hanging block culture; b, with flagella stained by Löwitz method. After Giddings.

In the soft rot caused by this organism in muskmelons, motile bacteria were observed in abundance by Giddings in 1907. Plating gave pure cultures which by inoculation tests were shown to be those of the causal organism of the rot. Decay is produced by solution of the middle lamella by enzymic action, the remainder of the walls withstanding the attack. The bacteria are thus

strictly intercellular. Wound inoculations in muskmelon generally gave complete decay in from three to seven days. Similar inoculation of citron and cucumbers resulted in decay, though inoculation into squash did not. No decay of muskmelon followed applications of the bacteria to unbroken surfaces.



FIG. 30.—Cultures of B. melonis on silicate jelly slants, 12 days' growth, (30° C.) After Giddings.

B. mycoides Flügge. (Group number –22.1– – –8–.)

Rods thick, 0.95 x 1.6–2.4 μ, usually in long threads, sporiferous. Spores elliptical, 1.3–1.48 x 0.7–0.9 mm. Gelatine colonies white with mycelium-like outgrowths; gelatine liquefied. Pellicle formed in broth. Gram positive.

This common soil organism has been held responsible for a disease of beets.[116]

B. nicotianæ Uyeda is ascribed as the cause of a tobacco wilt in Japan [117, 118] which closely resembles that caused by B. solanacearum in America.

The bacillus is 1–1.2 x 0.5–0.7 μ with rounded ends, actively motile by peritrichiate flagella. Spores are produced. A complete physiological study is to be found in the articles above cited.

Bacillus oleæ (Arc.) Trev. (Group number –22.333–0—.) C. O. Smith describes the organism as a motile rod with rounded ends, 1.5–2.5 x 0.5–0.6 μ. On agar slant growth thin, gray-white, spreading; colonies circular, whitish. On gelatine no liquefaction. Milk not coagulated. Distribution of flagella not stated.

In oleander tubercles on leaves and twigs, and in olive tubercles C. O. Smith [119] found bacteria which he regards as this species. Upon puncture inoculation in both olive and oleander, tubercles were produced. Controls were not diseased. The organism was reisolated from the

artificially produced knot with unchanged characters. E. F. Smith's results [65] do not agree with those of C. O. Smith. (See Pseudomonas savanastoi.)

B. oleraceæ Harr. (Group number 221.1113022.) [120-122]

This organism was studied by Harrison in 1901 in Canada where it was found associated with a soft rot of cauliflower, cabbages and turnips. In the rotting tissue it was always present; it was isolated, and upon inoculation and cross inoculation characteristic infection followed. The organism was reisolated in unchanged character. The chemical products of the bacillus, secured by filtration, also produced the characteristic tissue changes. Sections of diseased tissue showed the bacteria in the intercellular spaces, occupying the position of the middle lamella which was softened and eventually dissolved by the bacterial enzymes.

Harding and Morse [33] from their extensive studies conclude that this form is identical with B. carotovorus. See p. 42.

B. omnivorus v. Hall is described by van Hall [123] as the cause of a soft rot of iris shoots and rhizomes. According to Harding & Morse [33] it does not present characters sufficient to distinguish it from B. carotovorus. See p. 42.

A species closely related to B. omnivorus is described by Uyeda [124] as the cause of a disease of Zingiber. The organism was isolated and studied and the disease produced by inoculation with pure culture.

B. oncidii (Pegl.) Stev. is mentioned [126] as the cause of an orchid leaf spot.

B. oryzæ Vogl. has been mentioned as the possible cause of brusone [125] of rice.

B. phytophthorus Appel. (Group number 221.21230—.) A non-sporiferous rod, 0.6–0.8 x 1.5–2.5 μ, actively motile by peritrichiate flagella. Gram negative. It rots potatoes, cucumbers, etc.; is aërobic or a facultative anaërobe; grayish white on agar; surface colonies round, smooth; gelatine liquefaction moderate; bouillon clouded; no indol; no gas. Nitrate changed to nitrite. Milk coagulated and casein precipitated. Opt. 28–30°. T. D. P. 47°.

It was described by Appel [127] of Berlin as the chief cause of potato black-leg. The description given above is by E. F. Smith [128] and was made from Appel's organism. Smith also isolated it from potatoes grown in Maine and in Virginia.

It is closely related to but is not identical with B. solanisaprus and B. atrosepticus.[128]

B. populi Brizi is said to cause galls on the poplar [129].

B. pseudarabinus R. G. Sm.[130] is capable of producing on inoculation a crimson-red gum in the vessels of sugar cane and is perhaps responsible for a disease showing this symptom.

B. rosarum Scalia is the name given to a very imperfectly described organism said, on scant evidence, to be the cause of rose tumors or crown galls.[48]

B. sesami Malk.[66] Malkoff in infection experiments caused a disease of sesame with this organism.

B. solanacearum E. F. Sm. (Group number 212.333–8—.) A medium sized, easily stained, strictly aërobic bacillus with rounded ends; about 1½–3 times longer than broad; 0.5 x 1.5 μ. Motile, sluggish or active; flagella long, diffuse. Spores not known. Zoöglœa occur in liquid media as small, white flecks or as surface rings. It grows well at 20–30°. Milk is saponified with no casein precipitation or acidity. Gelatine not liquefied. Agar surface colonies, dirty-white. Agar streaks first dirty-white, later yellowish to brownish-white, then brown. On potato as on agar, but darker, with substratum and fluid browned. No gas from cane sugar, lactose, maltose or dextrose.

The disease caused by this bacillus upon tomato and other plants was early studied by Halsted [131-133] and perhaps by Burrill.[134-135] Halsted made inoculations which produced the disease but he did not use pure cultures. The first complete account of the causal organism was given by E. F. Smith [136, 137] in 1896.

In its hosts the bacillus is found in the pith, in the xylem which is browned, and more rarely in the bark. From the cut ends of infected ducts bacteria exude as a viscid ooze and the diseased ducts may be traced to great distances through the plant, even from root to leaf. From the bundles the organism later invades other tissues.

Needle prick inoculations in tomatoes and potatoes with pure cultures, were followed after several weeks (tomato) by typical disease. Inoculations in Irish potato resulted similarly, though in this host the parenchyma and bark were eventually invaded, and the tuber was reached through its stem end and rotted. In South Carolina, Smith noted the disease on egg plants and crude cross

inoculations were made to tomato. Smith demonstrated experimentally the efficiency of the potato beetle in transmitting the disease.

The disease was described for tobacco by Stevens [138] and Stevens and Sackett.[139]

Successful inoculations were reported upon tobacco by E. F. Smith in 1909 [140] though in his earlier trials tobacco and pepper gave negative results when inoculated with this bacillus. In addition to the above hosts it is known to grow upon Datura, Solanum nigrum, Physalis and Petunia.

B. solanicola Del. was reported as the cause of a potato stem disease.[141]

B. solaniperda Mig. (Group number 121.----0--.) A rod, 2.5–4 x 0.7–0.8 μ, with rounded ends, often in long chains; actively motile; spores present. Agar colonies dirty-white; gelatine liquefied. This was shown by Kramer in 1890 [142] to be the cause of soft rot of potatoes. The organism was grown in pure culture and inoculated on potatoes producing the characteristic decay. The germs enter through the lenticels, consume the sugar, then attack the intercellular substances and the cell wall. Later the albuminous substances are destroyed.

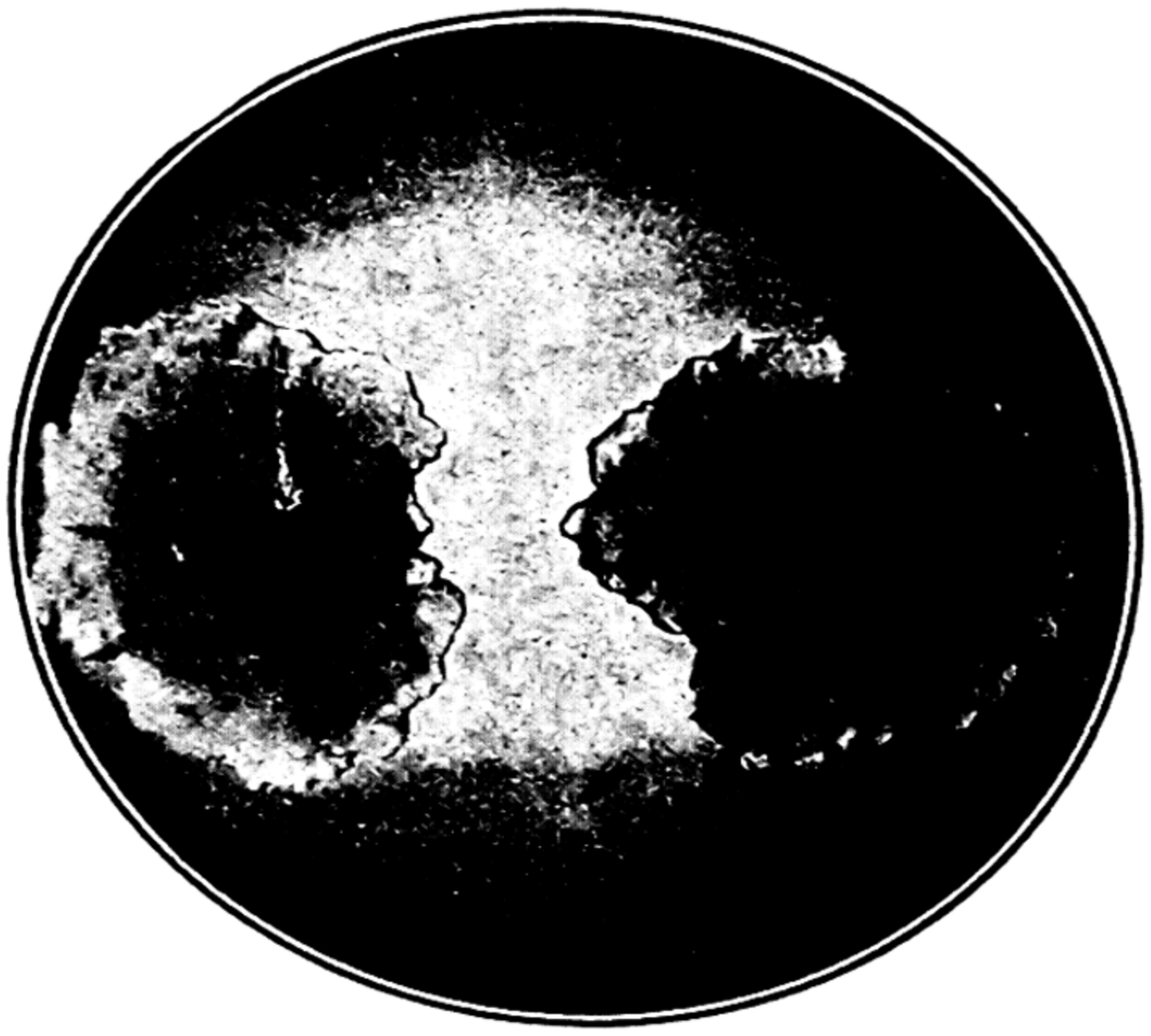


Fig. 31.—Surface colonies of B. solanisaprus. After Harrison.

B. solanisaprus Harr. (Group number 221.212–0–-.) [143] A bacillus with rounded ends, 1.5–4 x 0.6–0.9 μ, variable in culture; no capsule; actively motile by 5–15+ peritrichiate flagella; no spores seen. Gram negative. Gelatine colonies, punctiform 0.25 mm. at two days; gelatine stab filiform. Liquefaction noticeable on the thirty-fifth day. Agar colonies punctiform at two days, 1–5 mm., gray-white, slimy, flat. Bouillon turbid with fine sediment; ring, and thin band present; milk curdled.

Gas only in mannite and lactose. Nitrate reduced to nitrite. Opt. 25–28°. T. D. P. 54°, 10 min.

It was found constantly associated with a type of potato disease which Harrison regarded as distinct from black-leg and from the disease caused by B. solanacearum. It was repeatedly isolated from diseased tubers, stems and leaf veins and occurred in practically pure culture in freshly infected tissue.

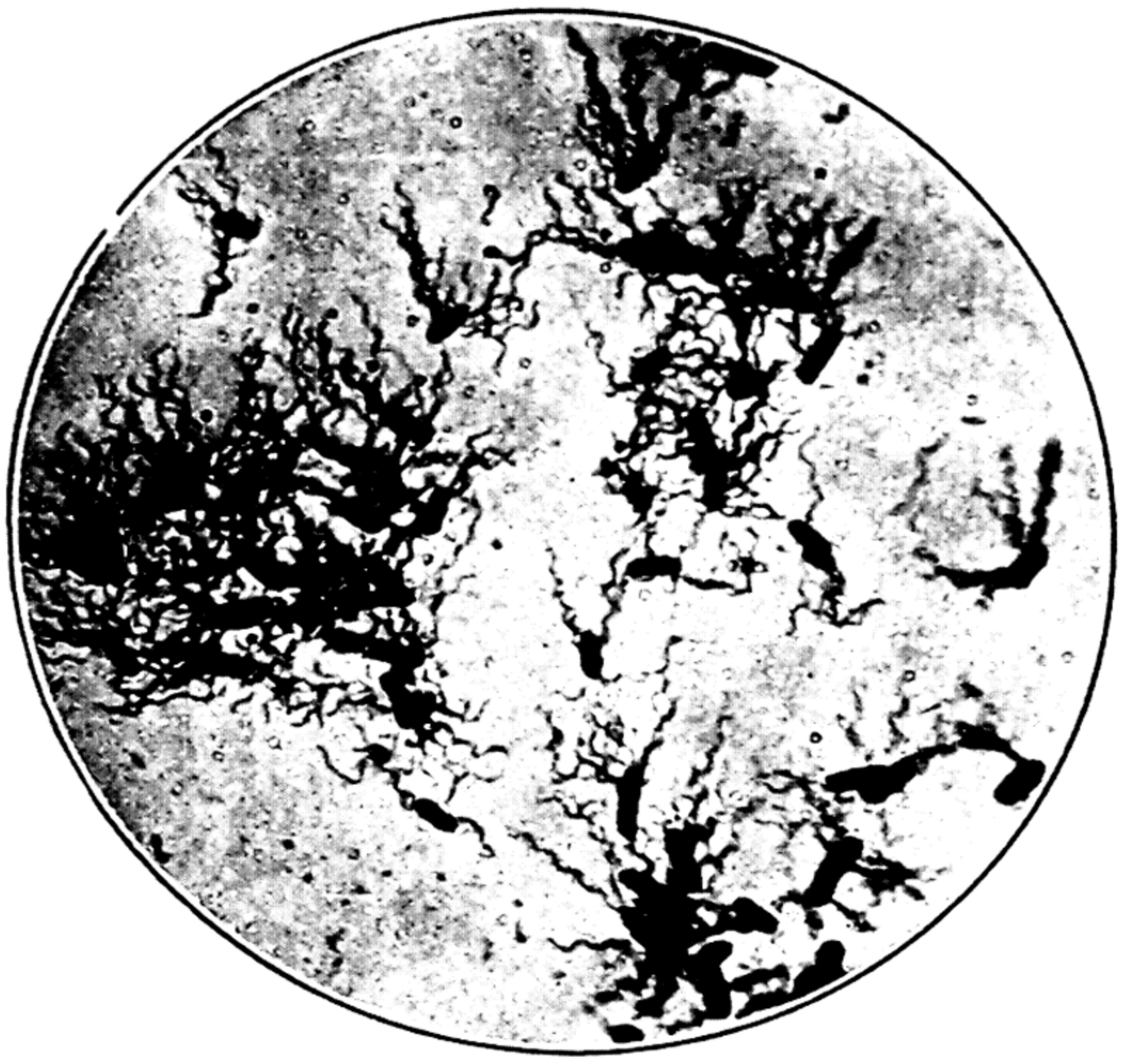


FIG. 32.—B. solanisaprus, from agar 24 hours. After Harrison.

The organisms first appeared in the ducts and thence invaded the surrounding tissue, dissolving the middle lamellæ and producing cavities. Inoculations of pure cultures into healthy plants produced characteristic lesions and the organism was reisolated. Characteristic enzymic action was observed on placing precipitated enzyme on slices of potato.

B. sorghi Burr.[144] Rods 0.5–1 (usually 0.7) x 1–3 (usually 1.5) μ, cylindrical or oval, motile, spore-bearing, non-liquefying. Colonies on agar, white to pearly. In broth with a white smooth membrane.

The bacillus was recognized as the cause of a sorghum blight by Burrill and this view was confirmed by Kellerman & Swingle through [145] inoculation experiments.

B. spongiosus A. & R. [146] causes gummosis of cherry in Germany.

B. subtilis (Ehr.) Cohn.

Straight rods, often united in threads, 0.7 x 2–8 μ. Sporiferous. Spores central or lying near one pole; germination equatorial. Flagella, 6–8, peritrichiate; gelatine liquefied; gelatine colonies

bordered by numerous fine filamentous outgrowths. Growth on slant agar gray. It is reported as the cause of vegetable rot.[147]

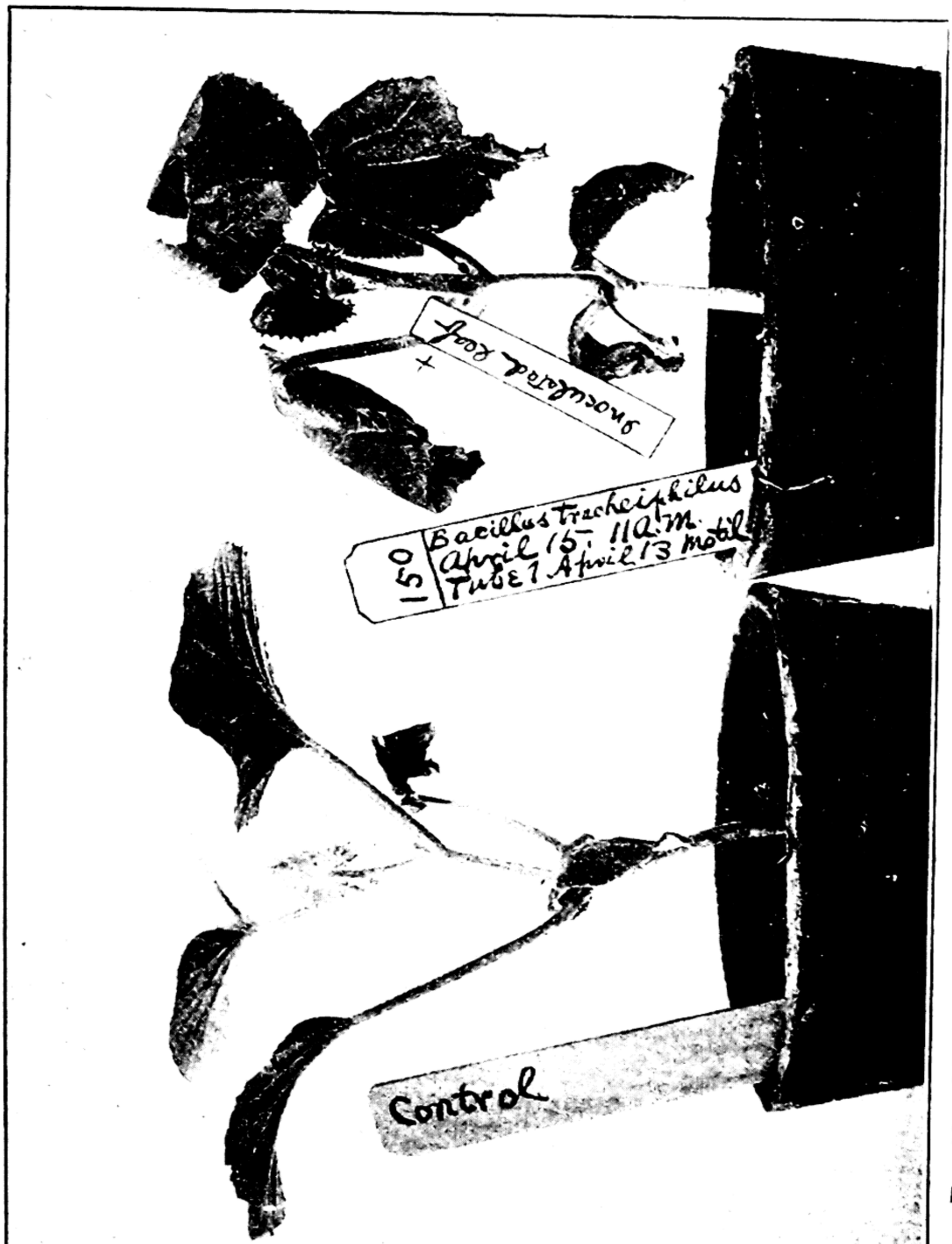


FIG. 33.—Muskmelon plant inoculated with a pure culture of B. tracheiphilus. After Smith.

B. tabacivorus Del. is recorded on tobacco stems.[3]

B. tabificans Del.[148] which perhaps belongs to the genus Bacterium is reported as the cause of a beet disease in France.

B. tracheiphilus, E. F. Sm. (Group number 222.——03–.)

Bacillus 1.2–2.5 x 0.5–0.7 μ, variable, actively motile in young cultures. Capsulated, no spores, peritrichiate. No gelatine liquefaction. On agar thin, smooth, milk-white. No gas, aërobic or facultative anaërobic. Milk not curdled. T. D. P. 43°, 10 min.

This pathogen was first reported by E. F. Smith without description in 1893 [149] and more fully in 1895.[150] It is found filling the vessels of cucurbits, (musk melons and cucumbers) affected with wilt. Smith produced the disease artificially by puncture inoculations on the blades of leaves with the white sticky fluid from infected veins. The inoculated plants showed symptoms of wilt after four days and sixteen days later the ducts of the vine were found to be plugged with bacteria. The organism was then isolated from this artificially infected plant. The cultures thus obtained were carried by transfers over winter and in December were used successfully to infect cucumber plants. Control plants were never diseased. The ready growth of the organism in the vessels is attributed to the alkalinity of the latter; the failure to grow in the parenchyma is attributed to its acidity.

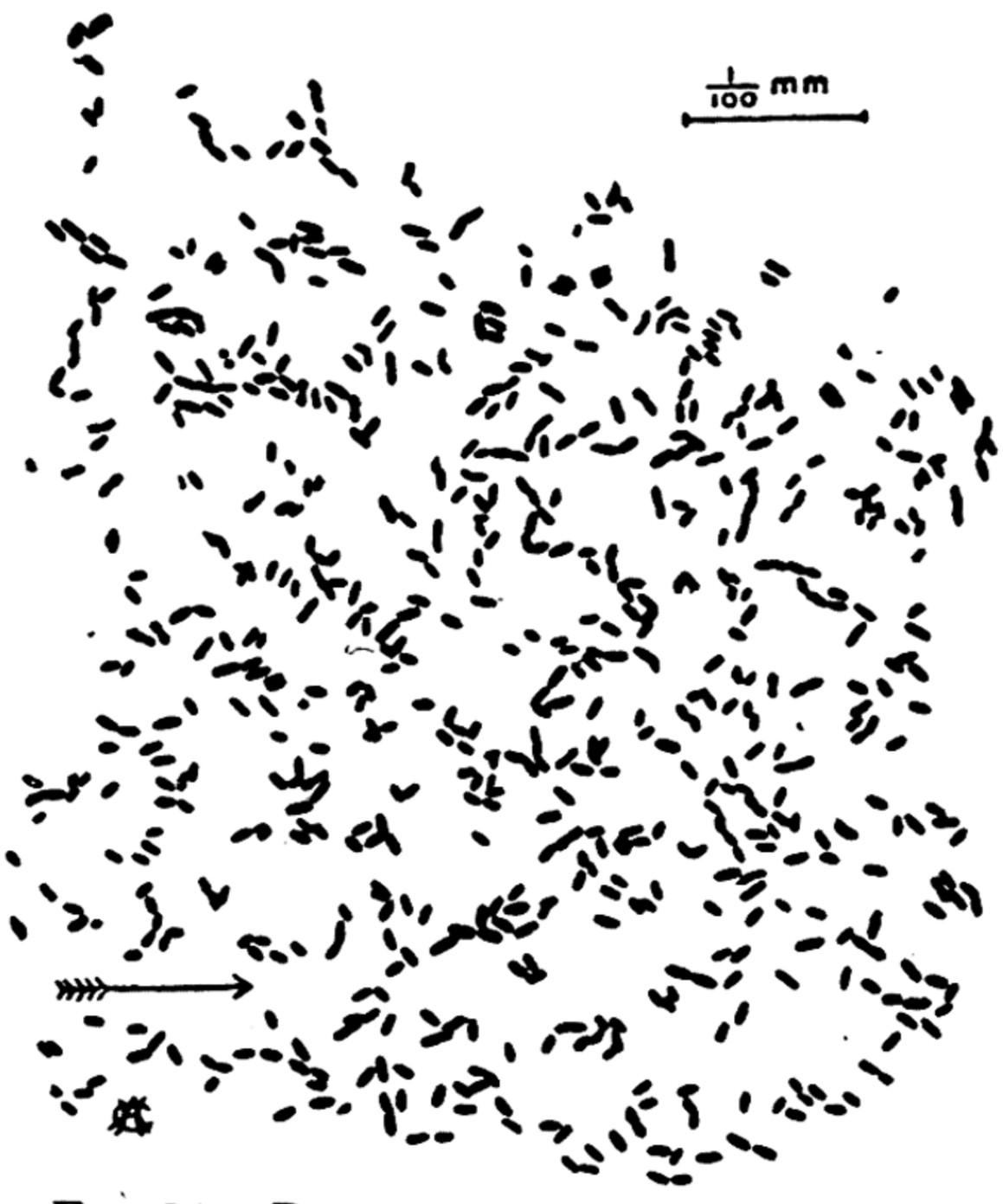


FIG. 34.—B. tracheiphilus. After Smith.

B. uvæ Cug. & Mac. is reported as causing injury to young grape clusters.[151] It is perhaps identical with B. ampelopsoræ.

B. vulgatus (Flügge) Mig. This organism is found as small thick rods with rounded ends, or is often paired or in chains of four; sporiferous. Gelatine colonies round, liquefaction rapid. Growth on agar dirty-white.

It has been shown capable of causing rot of various vegetables.[152]

B. zeæ Burr. is the name applied to a bacillus isolated from diseased corn plants by Burrill in 1887–1889.[153, 154] It is often

cited as the cause of a bacterial corn disease but the evidence of causal relation as well as the identity of the germ are not clear.

B. zinzgiberi Uyeda causes a disease of Zinzibar,[206] **B. sacchari** and **B. glangæ** are on sugar cane as the possible cause of sereh.[58]

An organism called **Clostridium persicæ-tuberculosis** by Cavara [155] is mentioned as cause of knot on peach trees.

Less known bacterial plant diseases. The literature abounds in references to what are regarded as cases of plant bacteriose, cases which as yet rest upon very incomplete evidence. In many of these bacteria are found in abundance in the diseased tissue but pathogenicity has not been proved by inoculation nor pure cultures made. Among such incompletely studied diseases may be mentioned those of geranium; [156-158] celery,[193] onion,[19, 159, 160] cucumber,[161] orchard grass,[162] lettuce,[26, 163] (one lettuce disease is due to a motile rod-shaped organism cultured and inoculated but not named,[164]) strawberries,[165-168] mulberry,[169] hemp,[170] calceolaria.[171]

There are also several obscure bacterial beet diseases; another cabbage rot due to Pseudomonas; [172] a decay of apples said by Prillieux to be due to a Bacillus;[173] the blossom-end-rot of tomatoes which is perhaps bacterial;[174] a cyclamen leaf spot; [175] a juniper disease; [176] a pine gall; [177] an ash bark disease; [178] and an ash canker; [179] an ivy canker; [180] a grape disease; [24] a salsify rot; [181] a carnation spot; [182] and a banana disease; [183] a gummosis of tobacco; [184] a disease of tobacco seedlings; [185] also perhaps the serious widespread mosaic disease of tobacco and an orchid gummosis.[186]

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* In the bibliographies the usual abbreviations for the states followed by B. or R. indicate respectively Bulletin or Report of the State Agricultural Experiment Station, B. P. I. or V. P. P. of the Bureau of Plant Industry or Division of Vegetable Physiology and Pathology of the United States Department of Agriculture, respectively.

Zeit.=Zeitschrift für Pflanzenkrankheiten.
Sc.=Science New Series.
E. S. R.=Experiment Station Record.
Ann. Myc.=Annales Mycologici.
Soc. M. Fr.=Société Mycologique de France.
Y. B.=Yearbook, U. S. Department of Agriculture.
C. R.=Compt. Rendu.
C. Bak.=Centralblatt f. Bakt. Par. u. Inf. Ab. II.
Other abbreviations are those usually employed or readily understood.
All bold face references, **000** will be found in the book bibliography, page 678.

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DIVISION III

EUMYCETES. TRUE FUNGI (p. 3) [1-17, 19, 22, 23, 29, 45-63]

The Vegetative Body is devoid of chlorophyll and typically consists of a more or less branched filament of apical growth, the **mycelium.** This mycelium may be cut into cells by partitions (**septa**) or may be **continuous,** i. e., without septa. The cells of the septate mycelium do not differ essentially from typical plant cells except in the absence of chlorophyll. They consist of masses of protoplasm, the **protoplasts,** bearing vacuoles and are more or less rich in oils, acids, gums, alkaloids, sugars, resins, coloring matter, etc., varying in amount and kind with the particular species and condition of the fungus. The protoplast is covered by a cell wall which consists of cellulose though often of a special quality known as **fungous cellulose.** The protoplast bears one or in some fungi two or more **nuclei.**

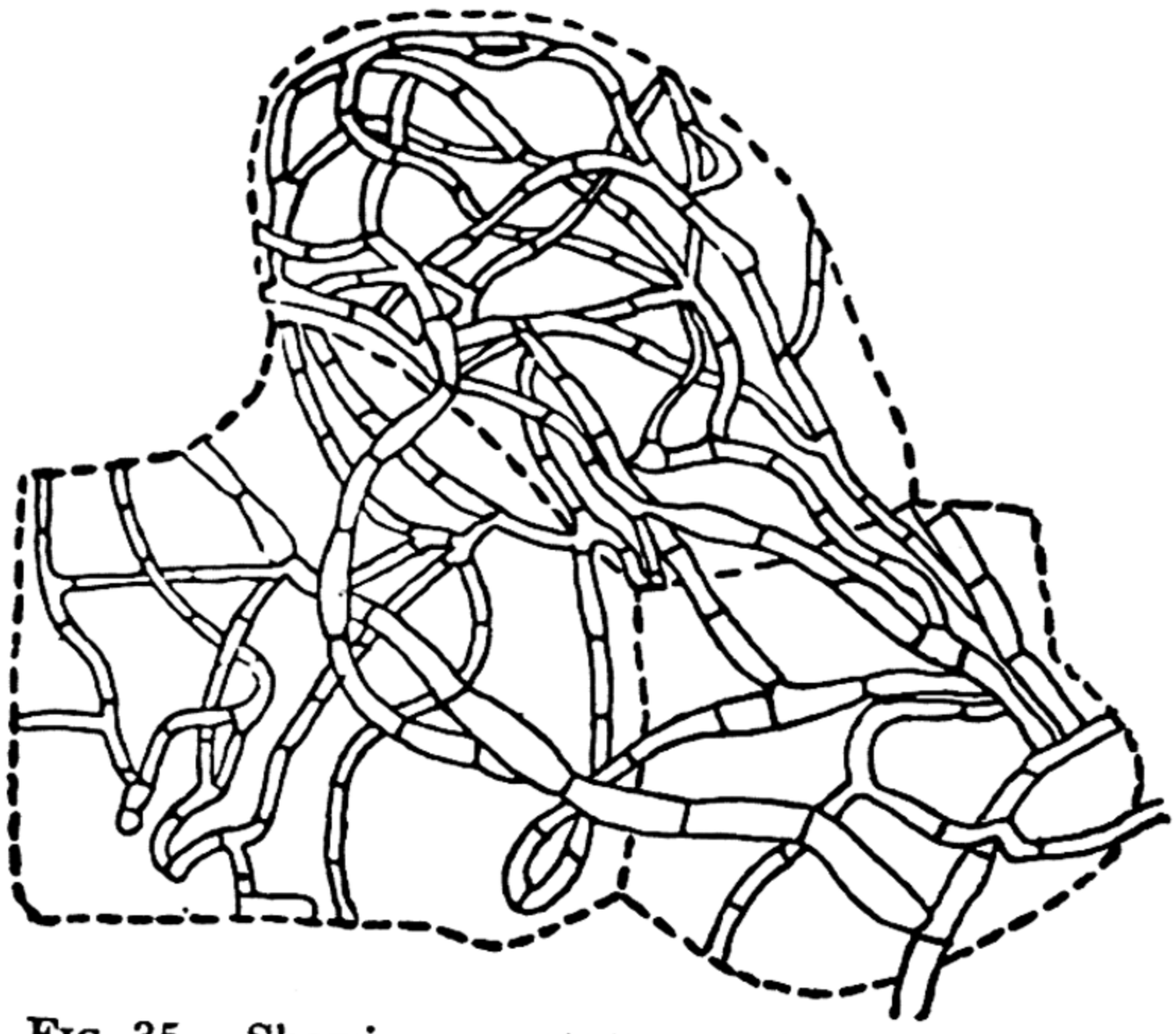


FIG. 35.—Showing a septate mycelium within host cells. After Stevens and Hall.

The vacuolation of the protoplasm, the mode of branching of the cells, their color, dimensions, etc., are in some cases quite characteristic.

In one class, the Phycomycetes, the active vegetative mycelium possesses no septa except such as serve to cut off the sexual or other reproductive organs or such as are found in senility. The

protoplasm is therefore continuous throughout the whole plant body and may be regarded as constituting one cell though it may be of great extent and bear very numerous nuclei. Such multinucleate cells, **coenocytes,** may be regarded as cell complexes with the walls omitted.

In one comparatively small order, the Chytridiales, there is often no filamentous mycelium and the vegetative body consists merely of a globular, irregularly spherical or amœboid cell. Such forms are thought by some mycologists to be degenerate, to have in remote time possessed a mycelium which has been lost owing to the present simple mode of life of the fungus, the needs of which no longer call for a filamentous body, while others [1] find here primitive forms of Phycomycetes, and trace their phylogenetic connection with the higher orders of the class.

Reproduction.

Vegetative. Most mycelia, if cut in bits and placed in suitable environment, continue to grow, soon equaling the parent mycelium in size if abundant nourishment obtains. Bits of diseased tissue, bearing mycelium, thus constitute ready means of multiplication and dispersal.

Asexual Spores. A spore is a special cell set aside to reproduce the plant. An asexual spore is a spore not produced by a sexual process. Manifold forms of asexual spores exist among the fungi. In some of the simplest cases, bud-like out-growths (**gemmæ**) appear on the mycelium; or portions of the mycelium itself are cut off by partitions and the protoplasm inside gathers into a mass and protects itself by a firmer wall than that of the mycelium, **chlamydospores.** In other cases special branches, **hyphæ,** are set apart for the purpose of bearing spores. If the spores are cut off from the tip of the branch they are known as **conidia** or **conidiospores,** and the branch bearing them is a **conidiophore.** Conidia may be borne singly or in false clusters caused by the youngest pushing the older conidia aside; frequently they are produced in



FIG. 36.—One form of conidium. Oidium. After Biolotti.

chains, **catenulate,** Fig. 36, owing to the development of one spore below another before the elder spore is shed. Conidia may be either **simple,** composed of one cell, or **compound,** composed of two or more cells. In compound spores each cell is at least potentially a spore and can germinate under favorable conditions and perpetuate the species. In many compound spores the germinating function is sacrificed by one or more of their component cells.

Conidiophores may consist of loosely branching, rather long hyphæ, or they may be short, innate, and in close clusters forming distinct spore bearing spots. Fig. 371. Such sporiferous spots when naked are called **acervuli.** Often the conidiophores are roofed over with a net-work of woven fungous threads thus constituting a special spore-bearing structure, the **pycnidium.** Figs. 37, 335. Conidiophores may be solitary or grow together in bundles or branch loosely as in Fig. 383.

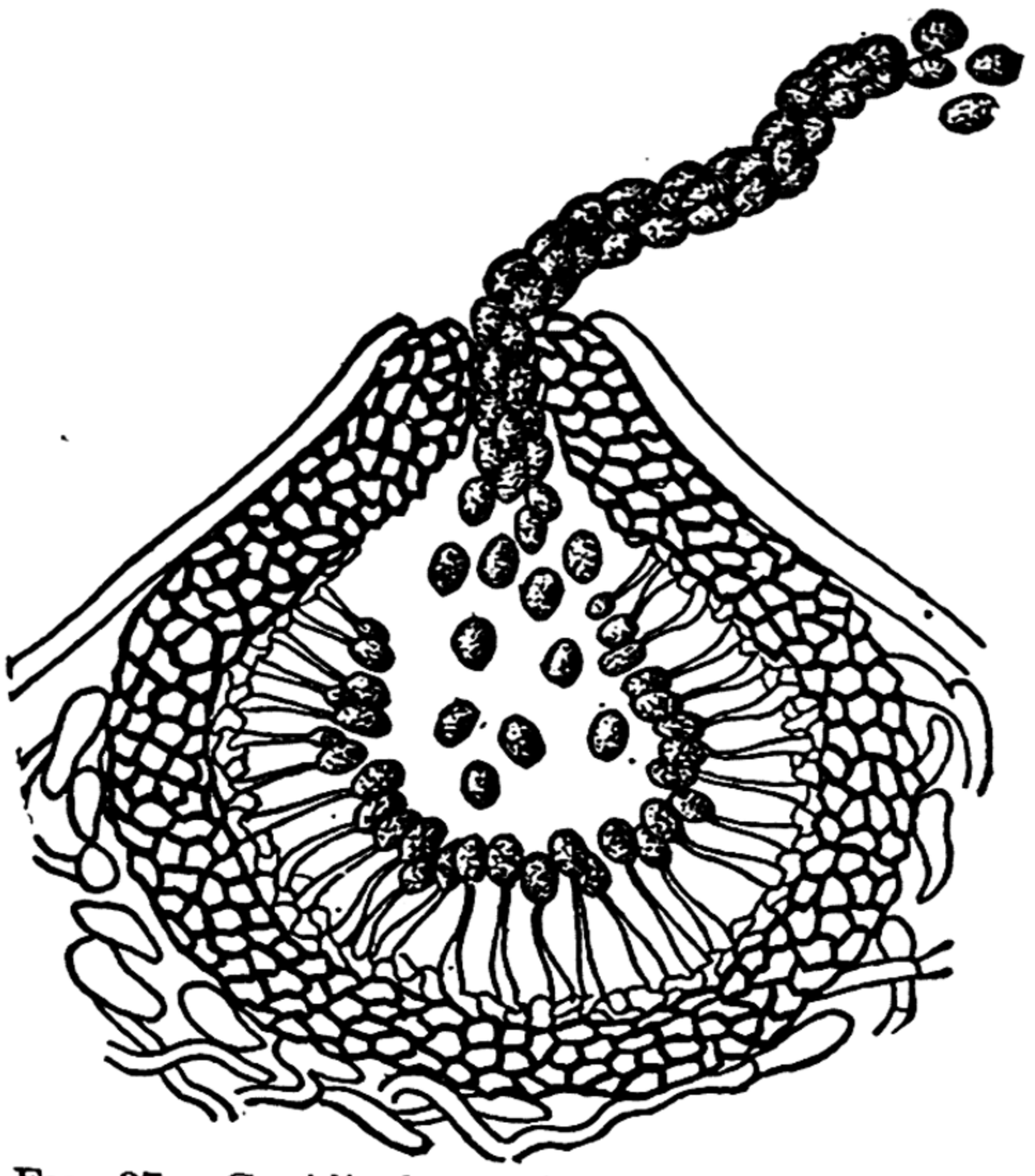


FIG. 37.—Conidia borne in a pycnidium. After Quaintance and Shear.

The **basidium,** Fig. 38, is a special kind of sporophore bearing at its apex usually four, or two, small projections, **sterigmata,** each of which produces one spore, for distinction called a **basidiospore.**

Some fungi bear the spores loose inside of the swollen tips of sporophores as in Fig. 68. The spore bearing structure is then called a **sporangium** and its stalk a **sporangiophore.** The **ascus** is another spore bearing structure. In it the spores are borne very much as they are in the sporangium but usually of definite number, 1, 2, 4, 8, 16, etc., eight being the most common number. Asci may be naked or covered, scattered or collected in groups.

When covered, the chamber in which they are borne is called a **perithecium,** Fig. 39; when on an open disk the disk is called an **apothecium,** Fig. 101.

According to their length of life spores are classed as: 1. **resting spores** whose function is to tide over unfavorable conditions, hence the common name "winter spore," and in contradistinction: 2. "Summer spores" which are produced in abundance in warm weather, germinate immediately, and can ordinarily live but a short time.

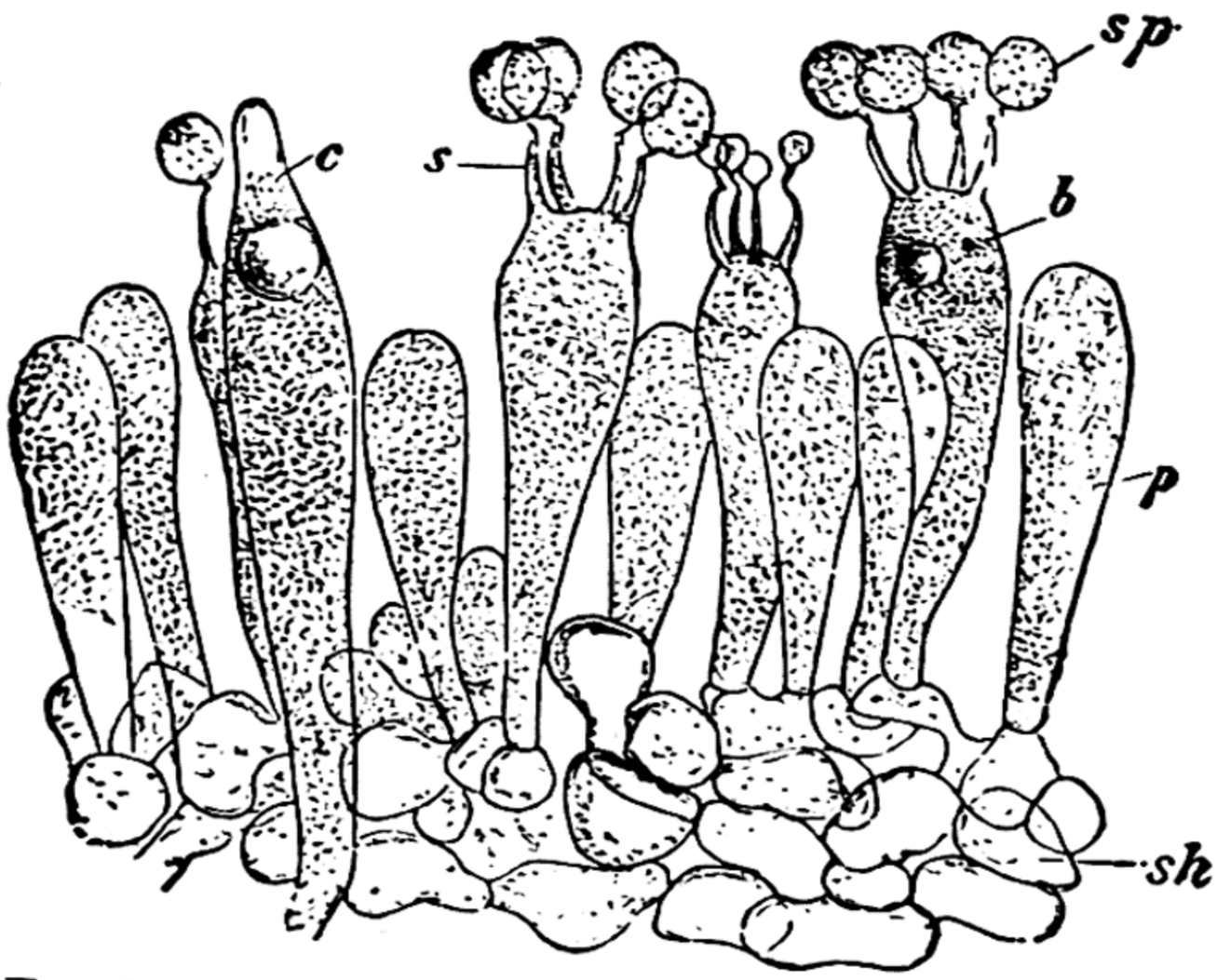


FIG. 38.—Basidia of various ages. After Schenck.

In some species the spores that are to function in water possess cilia, and the power of motion. These are **zoöspores** or **swarm spores,** Fig. 44.

At sporing time many kinds of fungi produce special structures for the bearing of spores. The fungous threads interweave to form a firm, or even a densely solid, mass and constitute a **false parenchyma.** Such are the stalks and caps of the mushrooms and of the shelving toadstools, the skin of the puff ball, etc. A cross section of such a structure appears much as a true parenchyma, a longitudinal section shows it to be merely a mass of interwoven fungous threads.

Sexual Spores are formed by the union of sexual elements, **gametes.** They are most conspicuous among the Oömycetes where the **antheridium** carries the **sperms** into the **oögonium,** fertilizes the **oösphere** and produces an **oöspore.** Figs. 53–55.

As a rule the sexual spores are produced toward the end of the vegetative period of the fungus. The asexual spores are produced earlier and for a longer period. Sexual spores are commonly resting spores.

Germination of spores. Under suitable environment mature spores germinate and eventually give rise to vegetative bodies

similar to that of the parent. The most usual mode is for the mycelium to rise directly from the spore. In other instances the spores produce zoöspores which migrate, come to rest, then develop a mycelium. In still other cases a short mycelium, **promycelium,** is formed and from this small conidia, **sporidia,** are made. Figs. 217, 240. These conidia give direct rise to the mycelium. Spores of some species may by gemmation lead a more or less prolonged existence without return to the mycelial stage.

Heat and Moisture Relation. Like all living things these organisms cannot develop without heat and moisture. The necessary degree of each varies with different species. Some

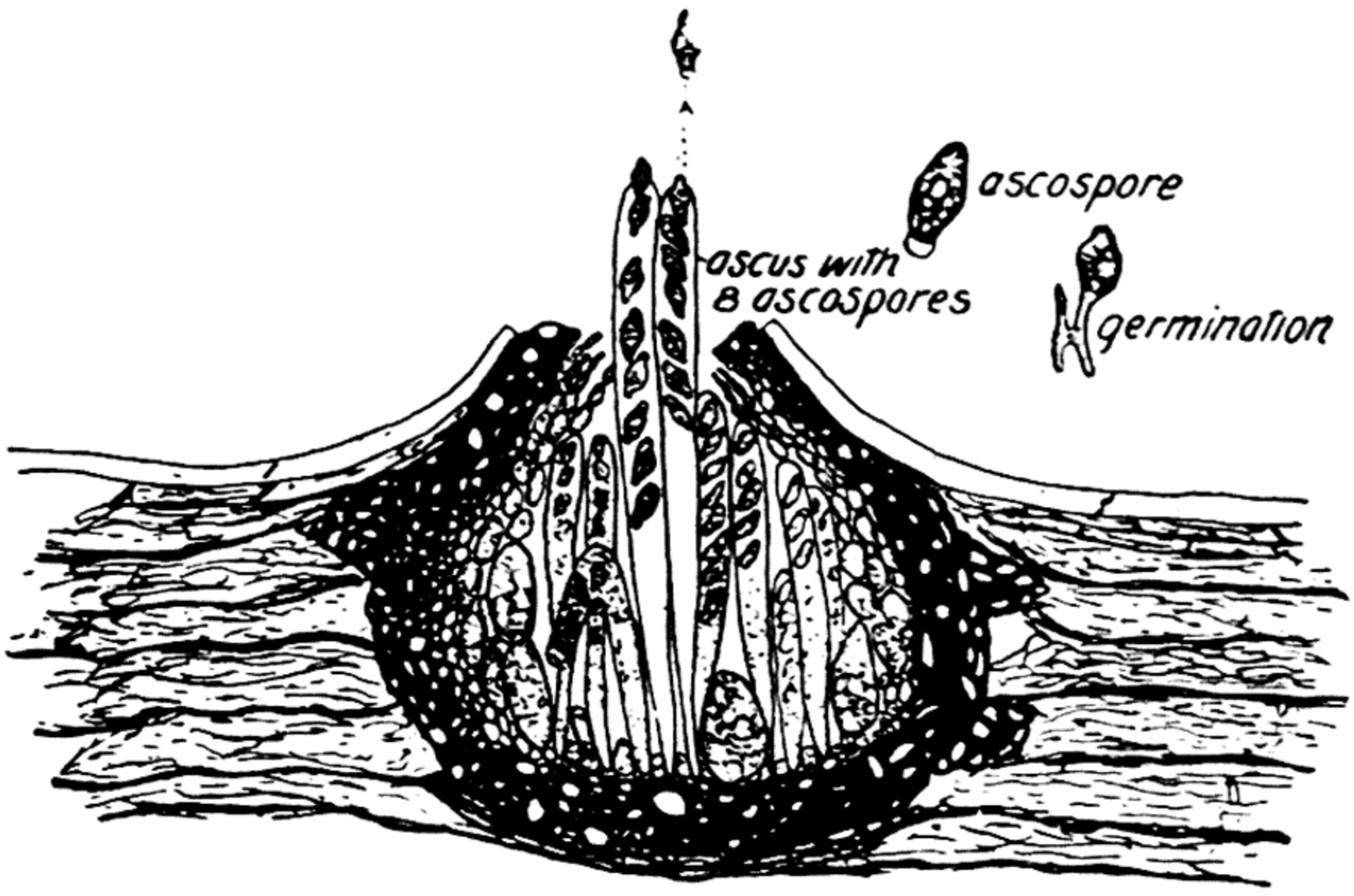


FIG. 39.—A perithecium with asci. After Reddick.

species are strictly aquatic, and must be surrounded with water; others can grow in comparatively dry situations. Generally speaking, however, dampness favors fungous development, and the growth of most fungi is more vigorous in a damp atmosphere than in a drier one. Similarly moderate warmth, as that of summer heat, favors fungous growth. Humidity and warmth combined are proverbial as producers of mold and mildew. So conspicuous is the coincidence of these conditions with fungous growth, that in the minds of many a warm damp air is the cause rather than the condition of fungous development.

Respiration with the fungi as with other plants and animals consists in oxidation, involving intake and consumption of oxygen accompanied by the giving off of carbon dioxide and water, and

since no photosynthesis occurs, this process is never masked as it is in the case of the chlorophyll-bearing plants.

In nutrition requirements there is great diversity; but in all cases carbon must be taken from some organic source. Starch, sugar, cellulose and kindred compounds are frequent sources of the carbon food supply. Nitrogenous foods are, generally speaking, not required in such abundance by the Eumycetes as by the bacteria and advantage may frequently be taken of this fact in isolating the fungi from bacteria by growing them on media poor in nitrogen, in which case the fungi often outgrow the bacteria.

The color of the fungi is determined largely by the constitution of the media upon which they grow.[2, 3, 4, 5]

Many fungi exhibit a peculiar heterœcism, that is, part of their life cycle is passed through upon one host, part of it upon another host, even of very distant botanical kinship. Thus among the rusts; in one instance part of the life cycle is upon the apple, the remainder upon the cedar tree. Fungi also exhibit **polymorphism,** i. e., in one stage they exhibit one spore form and in another stage another spore form totally different. In this way several apparently quite distinct types of spores and sporiferous structures may belong to the same species.

Classification of Fungi.[6, 7, 12, 21, 25, 28] The true fungi in themselves constitute a very large group made up of diverse forms, many of which are as yet little known. Any satisfactory system of classification is impossible until much more knowledge is gotten regarding their morphology, cytology, life histories and especially their relations to their hosts. According to present knowledge they comprise very numerous species distributed in three classes as follows:

KEY TO CLASSES OF **Eumycetes**

Mycelium continuous in vegetative stage	Class 1. **Phycomycetes,** p. 65.
Mycelium septate	
Spores in asci	Class 2. **Ascomycetes,** p. 113.
Spores on basidia*	Class 3. **Basidiomycetes,** p. 298.
Not as above; spores on conidiophores, naked, or in pycnidia; or spores quite unknown	Fungi Imperfecti, p. 475.

* In the rusts and smuts the promycelium is regarded as a basidium.

Class I. **Phycomycetes, Alga-like Fungi** (p. 64)

The Phycomycetes are characterized by the absence of septa in the mycelium except in sporing branches, where they occur to cut off the spore-bearing cells or the gametangia, and in old filaments. The body is multi-nucleate and sexual spores as well as asexual ones are usually, though not always, produced. Some of the Phycomycetes live in water and possess zoöspores, others are parasitic on land plants and bear conidia or sporangia. These may germinate either by germ tubes or by zoöspores. The characteristic fertilization consists of a union of two gametes which may be like in character (**isogamy**) or unlike (**heterogamy**). If the sexual organs are unlike the receptacle which bears the sexual spores is called the **oögonium,** its eggs before fertilization **oöspheres,** and the spores **oöspores.** The receptacle bearing the fertilizing gamete is the **antheridium,** and the fertilizing elements are the **sperms.** The sperms may be motile and swim or creep into the oögonium or the antheridium may develop a tube leading into the oögonium through which the fertilizing nuclei pass. In some forms which, by their sexual or asexual spores, show relation to the Phycomycetes the mycelium is wanting and the vegetative body is reduced to a single spherical or amœboid cell, which frequently lives in a purely parasitic manner entirely imbedded in the protoplasts of its host. This mode of life constitutes the strictest kind of parasitism inasmuch as the fungus derives its nourishment from the still living host cell.

Key to Orders of **Phycomycetes**

Sexual spores when present heterogamous. . . . . Subclass I. **Oomycetes,** p. 66.

Conidia absent; sexual spores and zoösporangia only

Mycelium poorly developed, frequently reduced to a single cell

Fruiting mycelium a single cell, or a group of cells in a sorus, forming either asexual resting spores or sporangia from the entire protoplasmic mass. . . . . 1. **Chytridiales,** p. 66.

Fruiting mycelium multicellular, some cells forming sporangia, others producing gametes and oöspores.	2. **Ancylistidiales.**
Mycelium well developed	
Fertilization by motile sperms. . . .	3. **Monoblepharidiales.**
Fertilization through an antheridial tube	4. **Saprolegniales,** p. 74.
Conidia present.	5. **Peronosporales,** p. 77.
Sexual spores isogamous, formed by the union of similar gametes..Subclass II.	**Zygomycetes,** p. 101.
Asexual spores several, in sporangia. . .	6. **Mucorales,** p. 102.
Asexual spores solitary, conidia.	7. **Entomophthorales,** p. 107.

Of these orders the Ancylistidiales which are parasitic upon Algæ, and the Monoblepharidiales which are saprophytic will not be considered further.

Subclass **Oömycetes** (p. 65)

In the Oömycetes there is pronounced difference between the male and female sexual organs. The oögonium is comparatively large, and contains one or more large passive eggs (oöspheres), which are fertilized by sperms, differentiated or not, which either swim to the oögonium by cilia, creep to it, or are carried to it by a fertilizing tube. Oöspores are in some species produced frequently and abundantly while in others they are entirely unknown. The asexual reproduction is by either conidia or sporangia.

Chytridiales (p. 65)

The members of this order are the simplest of any of the Phycomycetes. Many of them are single, more or less globose, undifferentiated cells, others have a more or less prominent haustoria-like mycelium, while but few have any approach to a true mycelial development. Most are intracellular parasites; a few of the more highly developed genera are intercellular parasites. With few exceptions reproduction is entirely asexual, all spores being formed directly from the vegetative cell. Zoösporangia and thick-

walled resting spores are produced. The zoöspores have either one or two cilia. There are over forty genera and two hundred species. The majority of the species are inconspicuous parasites of algæ and infusoria; but some genera, like Synchytrium and Urophlyctis, produce conspicuous sori and even cause hypertrophy of land plants.

KEY TO FAMILIES OF **Chytridiales**

Spores all asexual, or rarely formed by the union of free-swimming gametes	
Mycelium none	
Sporangia solitary.	1. **Olpidiaceæ,** p. 67.
Sporangia grouped into sori.	2. **Synchytriaceæ,** p. 69.
Mycelium present	
Mycelium of delicate, evanescent haustoria-like strands	
Mycelium limited; sporangia terminal.	3. **Rhizidiaceæ.**
Mycelium extended, sporangia terminal or intercalary.	4. **Cladochytriaceæ,** p. 72.
Mycelium of permanent hyphæ	5. **Hypochytriaceæ.**
Spores both sexual and asexual	
Gametes hetrogamous.	6. **Oöchytriaceæ,** p. 73.
Gametes isogamous.	7. **Zygochytriaceæ.**

Four only of these families have parasitic representatives on higher plants in America, the others being chiefly parasitic on algæ and infusoria.

Olpidiaceæ

This family which contains the simplest members of the order has no mycelium; the entire plant body consists of a single more or less globular or elliptic cell which never divides, but at maturity forms either a zoösporangium or an asexual resting spore which after a period of rest gives rise to swarm spores. All the species are endobiotic. The family contains some forty species but few of which are of economic importance.

Key to Genera of Olpidiaceæ

Vegetative body amœboid. . . . . 1. **Reessia.**
Vegetative body of definite form
  Sporangia free in the cells of the host
    Sporangial membrane very delicate, evanescent. . . . . 2. **Sphærita.**
    Sporangial membrane firm, swarm spores escaping by a definite opening
      Sporangium globular or ellipsoid
        Sporangium with only one or two openings
          Swarm spores uniciliate
            Vegetative cells globose or subglobose — 3. **Olpidium,** p. 68.
            Vegetative cells stellate — 4. **Asterocystis,** p. 69.
          Swarm spores biciliate — 5. **Olpidiopsis.**
        Sporangium with several openings — 6. **Pleotrachelus.**
      Sporangium elongate . . . . . 7. **Ectrogella.**
  Sporangial membrane united to the wall of the host cell. . . . . 8. **Pleolpidium.**

Olpidium A Braun

In this genus a single swarm spore invades the cell of the host and develops in its protoplasm. Later a cell wall forms and the vegetative body changes into a zoösporangium which develops a neck. This reaches to the outside of the host even though the fungus be developed several cells below the surface. The uniciliate zoöspores pass out through this neck to make their escape. Thick-walled resting spores are also formed.

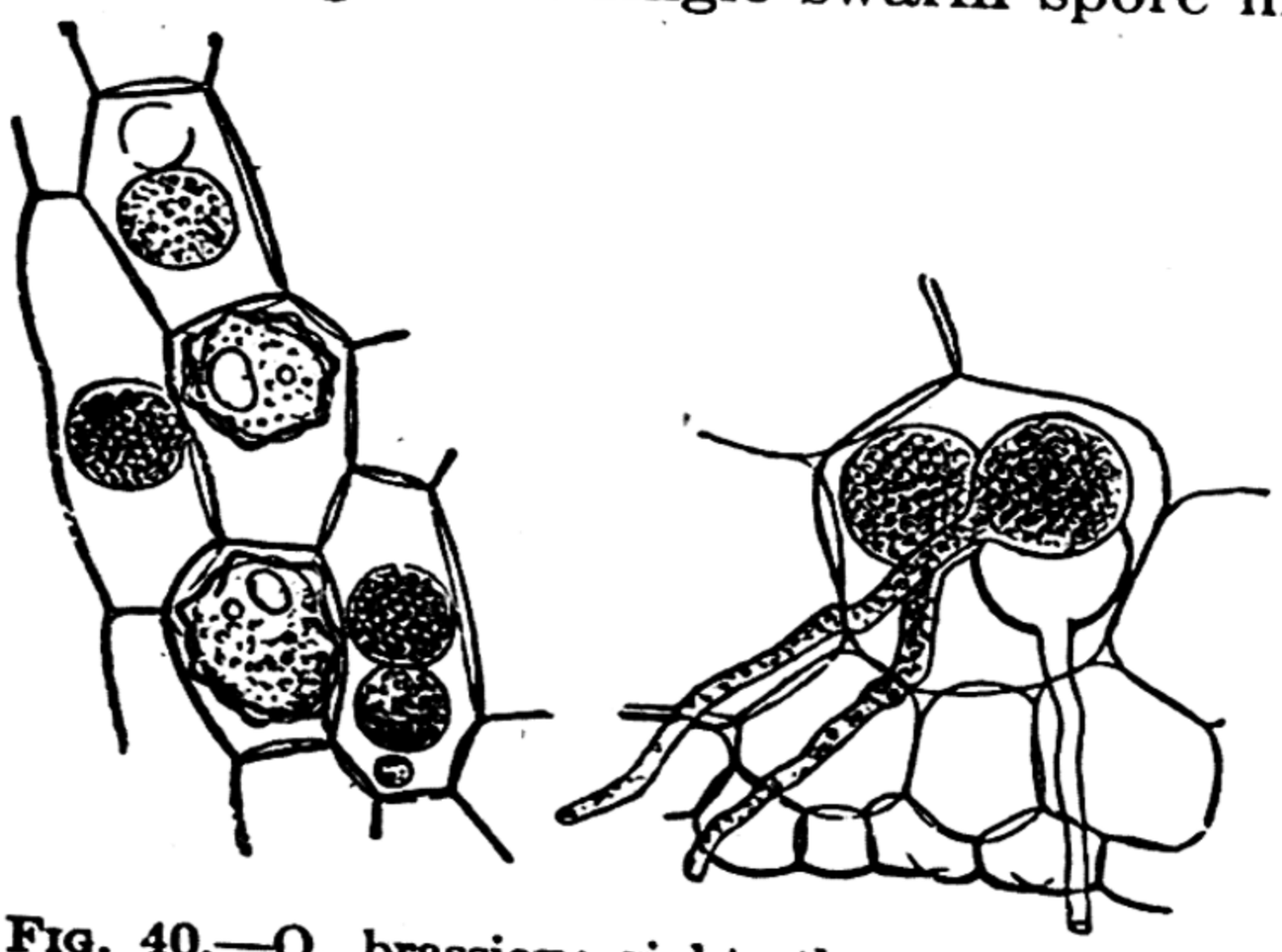


Fig. 40.—O. brassicæ; right, three sporangia in a cell; left, resting spores. After Woronin.

There are some twenty-five species most of which live as parasites on algæ, worms, pollen grains, etc.

O. brassicæ (Wor.) Dang.[6] is parasitic on quite young cabbage seedlings, sometimes infecting cells deeply seated in the host. The same or a nearly related species also attacks tobacco and several weeds.

Sporangia solitary or several in each infected host cell, globular; zoöspores numerous, globose, uniciliate; resting spores globose, with a wrinkled epispore which gives them more or less of a star-like appearance. Fig. 40.

Asterocystis de Wildeman (p. 68)

There is a single species, **A. radicis** d. Wild.[8] which differs from Olpidium in its stellate vegetative cell and the absence of the tube for the escape of the zoöspores, this being accomplished by the breaking away of the tissues of the host. The fungus attacks the roots of various plants, notably flax, Brassica and other crucifers, Plantago, Veronica and numerous grasses, producing chlorosis. It has not been reported from America.

A Chytridiaceous fungus of unknown genus thought to stand near the Olpidiaceæ and Synchytriaceæ has been described by Horne[7] as the cause of an Irish potato disease.

Synchytriaceæ (p. 67)

The infecting zoöspore invades the host cell and becomes parasitic upon the still living protoplasm. Hypertrophy of this and adjacent host cells is usually induced, resulting in the formation of a small gall around the infected cell. This gall is often colored and bears a superficial resemblance to a rust sorus. The parasite enlarges until it occupies nearly the whole of the host cell. In Synchytrium the one nucleus then enlarges and divides to produce very numerous nuclei.[9, 10, 11, 12] The whole mass then divides into segments regarded as sporangia, and each sporangium divides into numerous uninucleate parts, each of which develops into a zoöspore. In some species development is arrested before the division of the primary nucleus and the protoplast becomes spherical, invests itself with a thick wall and becomes a resting

spore. (Fig. 42.) After a more or less protracted period of rest this produces zoöspores.

The family includes some fifty species, all of which, except two small genera, are parasitic upon land plants.

KEY TO GENERA OF **Synchytriaceæ**

Zoösporangia formed by direct division of the entire plasma of the young fruiting body.

Swarm sporangia completely filling the host cell, membrane united to the wall of the host cell. . . . . 1. **Rozella.**

Swarm sporangia lying free in the host cell

Parasitic on algæ . . . . . 2. **Woronina.**

Parasitic on land plants. . . . . 3. **Woroniella.**

Zoösporangia formed by division of an initial cell to form a sorus of sporangial cells.

Sporangia formed directly from the full-grown plant body. . . . . 4. **Synchytrium,** p. 70.

Sporangia formed by the division of a thin-walled mother cell after its escape from the plant body. . . . . 5. **Pycnochytrium,** p. 72.

Synchytrium de Bary & Woronin

Upon reaching maturity the plant body develops directly into a sporangial sorus. Both zoösporangia and winter spores present.

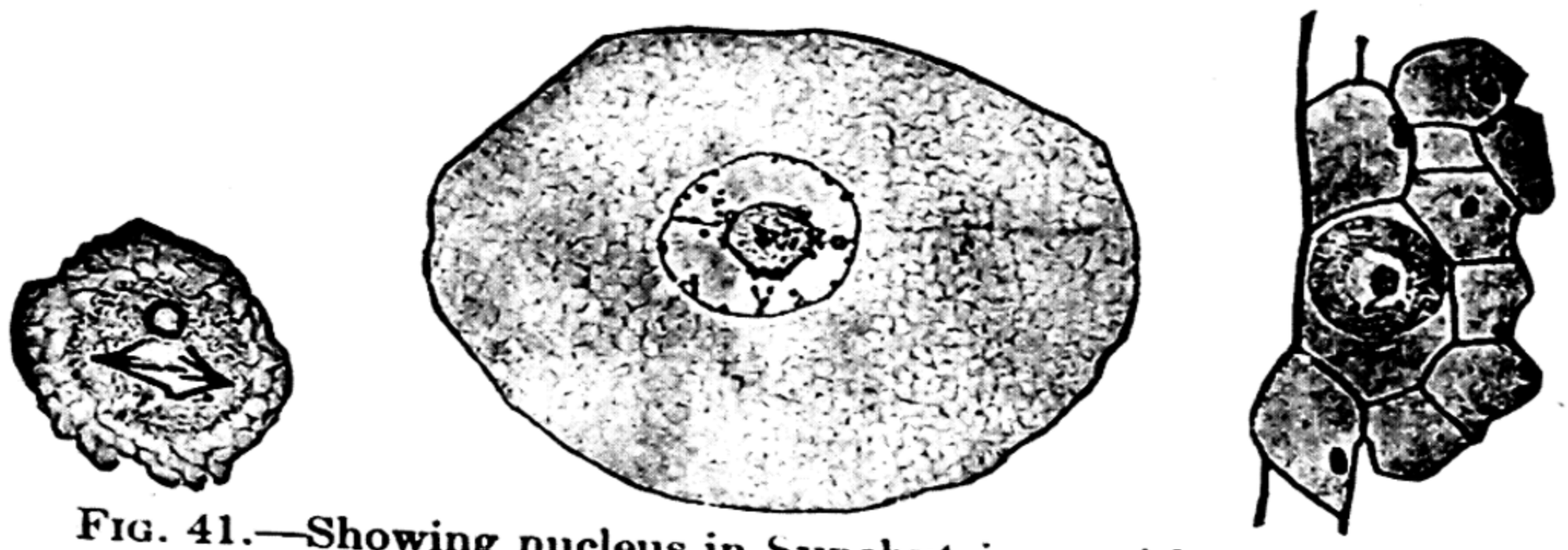


FIG. 41.—Showing nucleus in Synchytrium. After Stevens.

S. endobioticum (Schilb.) Perc., the cause of a very serious wart disease of the potato, was originally described as Chrysophlyctis endobioticum by Schilberszky[14] and transferred to Synchytrium by Percival.[13] It invaded America about 1909.[131] It was reported from Africa by Zimmermann.[15]

In summer the resting spores which average about 52 μ in diameter are found in abundance in the host cells near the surface, few in the outer layer, more below down to the sixth or eighth row of cells. Each resting spore contains several hundred roundish zoöspores which measure 2–2.5 μ. In spring the resting spores germinate, freeing numerous pear-shaped uniciliate zoöspores, which at first swim with a jerky motion but soon become amœboid. The summer sporangia may germinate without protracted rest, and also give rise to zoöspores. Another type of sporangium consists of thin sacs, produced singly or two to five in a sorus, each bearing numerous zoöspores somewhat smaller than those from the first type of sporangia.

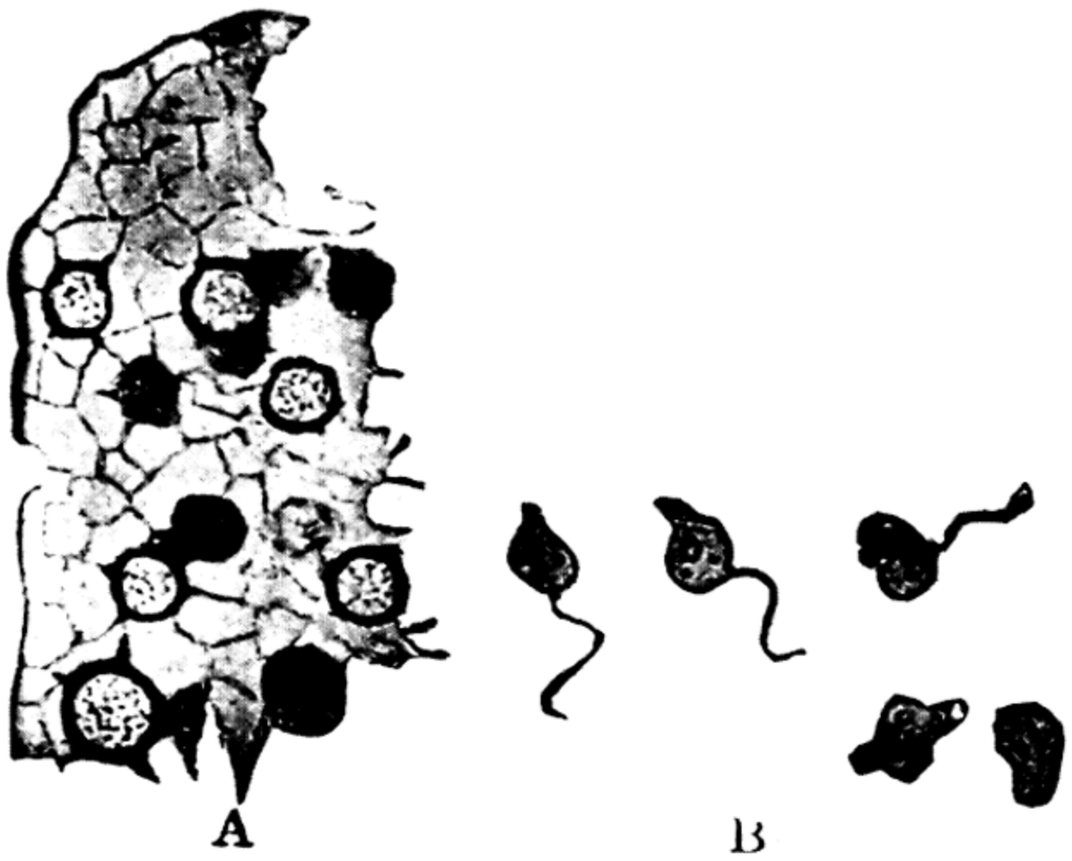


FIG. 42.—A, section showing sporangia or sporocysts; B, zoöspores, ciliated and amœboid. After Percival.

The zoöspores, says Percival, enter the potato apparently in the amœboid state in bud tissue of rhizomes and in the "eyes" of young tubers. Usually only one zoöspore enters each cell but occasionally more may do so. Crushed sporangia produced characteristic warts in three to four days when placed on susceptible parts. Successful inoculations were also made by Salmon and Crompton.[16] The cytology has been studied by Percival.[13] The full grown tumors vary in size from that of a pea to a hen's egg, and represent metamorphosed branch systems.

S. vaccinii Thomas [17-19] is the cause of a disease of the cranberry and related hosts. It forms numerous, small, reddish galls in which, deeply embedded, are the sori.



FIG. 43.—Gall of S. vaccinii. After Shear.

S. papillatum Farl.[20] occurs on Alfilaria in California.

Other species of Synchytrium are found upon dandelion, Œnothera, Geranium, Amphicarpa, Ornithogalum, clover, elm, etc., but as yet are not of economic importance in America.

Pycnochytrium Schröter (p. 70)

Only resting spores are known. In germination their protoplasmic contents emerges and forms a sporangial sorus.

P. anemones (D. C.) Schr. is common on various species of Anemone; **P. globosum** (Schr.) Schr. on the violet, blackberry, maple, etc. None of the species are of any considerable economic importance.

Cladochytriaceæ (p. 67)

A branching mycelium runs through or between the cells of the host drawing nourishment from many cells. Sporangia are either apical or intercalary and contain uniciliate zoöspores. Resting spores are also produced. There are about a half dozen genera and some thirty species.

Key to Genera of **Cladochytriaceæ**

Resting spores only known. . . . . 1. **Physoderma.**
Swarm spores only known
  Intracellular and endophytic
    Swarm spores at first ciliate, becoming amœboid. . . . . 2. **Cladochytrium,** p. 72.
    Swarm spores not becoming amœboid 3. **Pyroctonium,** p. 73.
  Living free among the hosts
    Sporangia opening by a pore. . . . . 4. **Amœbochytrium.**
    Sporangia opening by a lid. . . . . 5. **Nowakowskiella.**

Cladochytrium Nowakowski[21]

The genus contains about ten species of intercellular parasites with branched mycelial threads. The zoösporangium is globose, and opens by a distinct mouth which develops a tube for the escape of the zoöspores much as does Olpidium. Resting spores are not known.

The most important species are **C. tenue** Nowak. on Acorus and Iris; **C. graminis** Büsg.[53] on various grasses, **C. violæ** Berlese on violets.[22]

C. viticulum Pru.[23] and **C. mori** Pru.[24] have been described on grape and mulberry, but further study is very desirable.

C. brassicæ E. & B.[25] is described from dead leaves of cabbage.

C. cæspitis G. & M.[26] occurs in France on Lolium.

Pyroctonium sphæricum Pru.[27] was reported in 1894 as the cause of wheat disease in France but has not since been found.

Oöchytriaceæ (p. 67)

The plant body is either an undifferentiated cell or a well developed mycelium; reproduction by means of asexual swarm spores and sexual resting spores. Of the three genera only one is of economic importance.

Key to Genera of **Oöchytriaceæ**

Mycelium entirely lacking.	1. **Diplophysa.**
Mycelium present	
Mycelium producing a single gametangium.	2. **Polyphagus.**
Mycelium producing several gametangia	3. **Urophlyctis,** p. 73.

Urophlyctis Schröter

Mycelium endophytic, producing zoösporangia on the surface of the host and thick-walled oöspores within the tissues; zoöspores uniciliate. The genus contains some half dozen species all of which are parasitic on higher plants.

U. leperoides (Sacc. & Trab.) Magnus [28, 29] causes "beet root tumor," in North Africa and Western Europe. The rootlets of the upper portion of the root are attacked and develop tumorous growths, sometimes as large as a walnut. The infection is super-

ficial and does not extend to the fleshy tap root. The development of the spores is the typical method for the genus, the antheridium persisting at the base of the oögonium and retaining its hyphal connection, while the oögonium becomes free just before conjugation. The oöspores are subglobose, depressed on one side, smooth, brown, 45–50 x 30 μ.

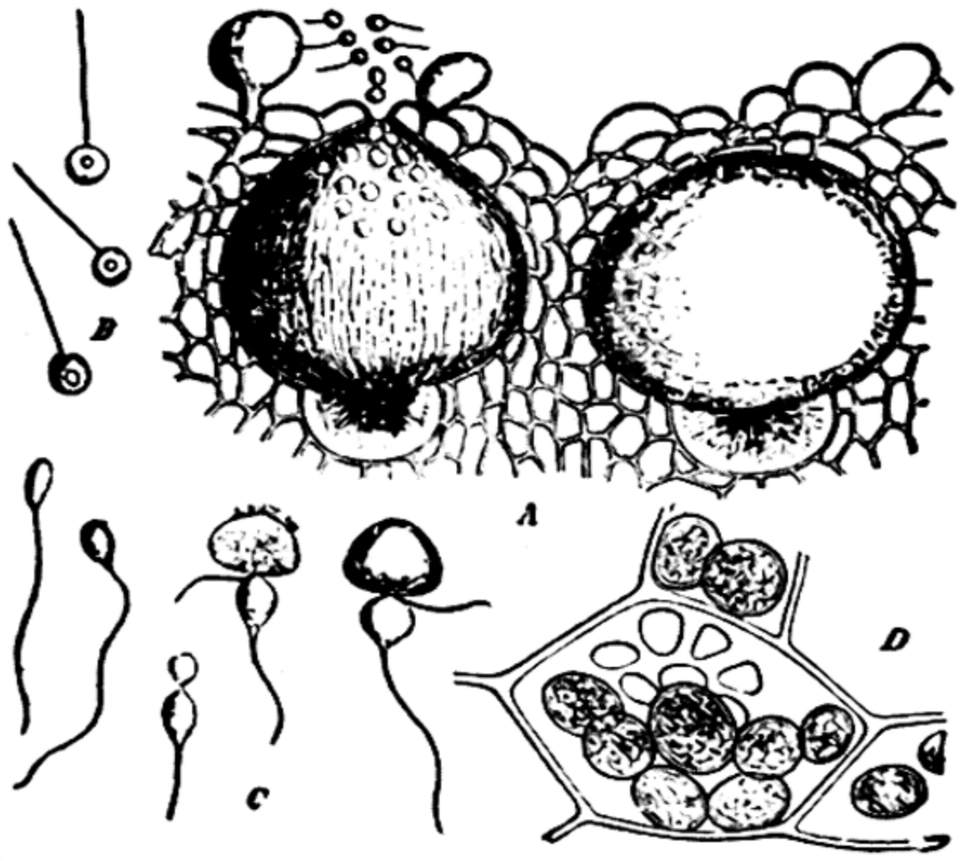


FIG. 44.—Urophlyctis pulposa. *a*, zoösporangium; *b*, zoöspores; *c*, oöspore formation; *d*, mature oöspores. After Schröter.

U. pulposa (Wallr.) Schr., a closely related species occurs on the aërial portions of Chenopodium and Atriplex.

U. alfalfæ Mag.[30, 137, 138, 141, 142] causes a crown gall of alfalfa in America and Europe. The disease is quite similar to that described above for the beet.

U. trifolii (Pass.), Mag., a closely related species, forms small, glassy, globose pustules on the leaves and petioles of various species of clover in Europe.

U. hemispherica (Speg.) Syd.[31] in South America, **U. kriegeriana** Mag.[31] in Europe and **U. pluriannulata** (B. & C.) Farl.[32] in America form Synchytrium-like galls on various umbelliferous genera. All may belong to the same species. **U. major** Schr. and **U. rubsaameri** Mag. infect respectively the leaves and the roots of Rumex.

Saprolegniales (p. 66)

Asexual reproduction is mainly by biciliated spores formed in large numbers in sporangia of various shapes. Sexual spores, often apogamous, are produced in most genera, much after the fashion of those of the Peronosporales except that more than one oöspore is frequently formed in one oögonium.[132]

The order consists of fifty or more species, mostly parasites or saprophytes upon aquatic organisms. One species of the genus Achlya causes serious disease in young fish.

There are three families:

Key to Families of Saprolegniales

Vegetative mycelium of thick tubular hyphæ; aquatic; zoösporangia cylindrical not much thicker than the mycelium	
Filaments uniform, not constricted.	1. **Saprolegniaceæ.**
Filaments constricted regularly.	2. **Leptomitaceæ.**
Vegetative mycelium of thin hyphæ, mostly parasitic or saprophytic on plant tissues; zoösporangia much broader than the mycelium, mostly globular	3. **Pythiaceæ,** p. 75.

Dictyuchus Leitgeb.

This genus of the Saprolegniaceæ contains the only parasite genus in the first two families.

Sporangia cylindric or clavate, swarm-spores becoming walled within the sporangium and emerging singly through its lateral walls. The genus is usually saprophytic but, **D. monosporus** Leit. is said by Halsted to be a serious hyacinth enemy.[139]

The other members are mainly on dead or diseased insects or other animals that are in water or are on diseased algæ or in water-slime.

Pythiaceæ [133]

This family shows affinity with both the Peronosporales and the Saprolegniales and is sometimes classed with the one, sometimes with the other. It consists of three genera and about twenty species characterized by a mycelium of very delicate hyphæ which show no differentiation into sterile and fertile regions. The species are either aquatic or terrestial; in the latter case they are soil fungi that grow to maturity upon seedlings. When of aërial habit the sporangia become conidial in character, that is, they are detached from the hypha before the discharge of the zoöspores.

Zoösporangia elongate.	1. **Nematosporangium.**
Zoösporangia spherical or oval, not linear	
Zoöspores formed outside of the zoösporangia.	2. **Pythium,** p. 76.
Zoöspores formed within the zoösporangia.	3. **Pythiacystis,** p. 77.

Pythium Pringsheim [33] (p. 75)

The mycelium is found in abundance in and about the infected tissue as fine, branched continuous threads. These, in the terrestial



FIG. 45.—Cucumber seedlings. Pots 5, 6, and 8 inoculated with Pythium. Pot 7, Control. After Atkinson.

species, bear conidia on branches which are of the same character as the mycelium itself. The conidia germinate either by a rupture of the wall or by the formation of a beak-like process through which the protoplasm is extruded, after which it becomes differentiated into zoöspores. Gemmæ, very like the conidia in appearance, are also produced.

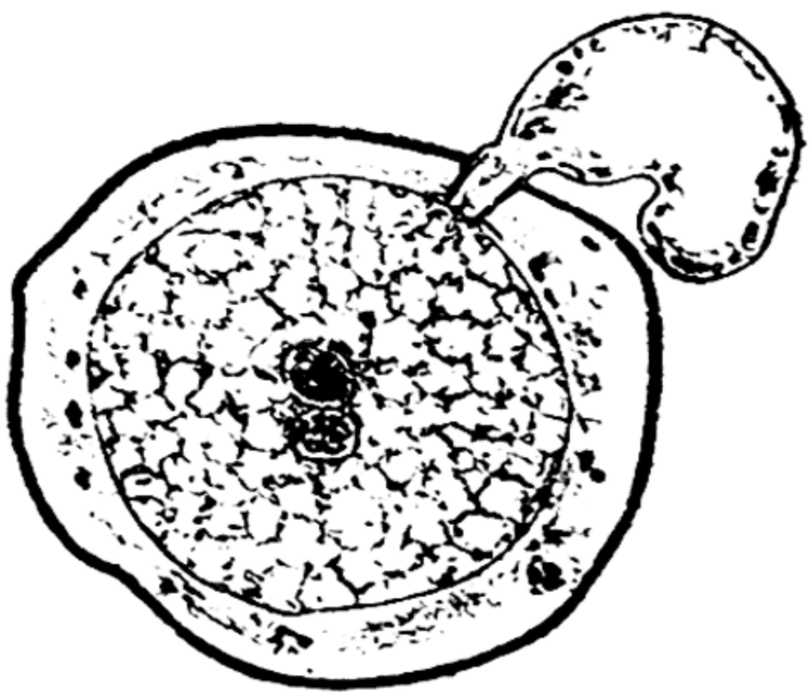


FIG. 46.—Fertilization in Pythium, showing oögonium, antheridium, oöspore, periplasm and the ♂ and ♀ nuclei. After Miyaki.

The oögonia are quite like the conidia and gemmæ in structure but develop oöspores within. The oögonium is at first multinucleate but as the oösphere matures all of the nuclei except one migrate toward the periphery, the periplasm, or degenerate in the oöplasm, resulting at maturity in an uninucleate egg. This is fertilized by one nucleus from the antheridium. No sperm is differentiated,

and the contents of the antheridium are carried over to the egg by a fertilizing tube. Members of the genus are aggressively parasitic only under most favorable environmental conditions of heat and moisture.

Some sixteen species are known.

P. de baryanum Hesse. is most common [33-37] as the cause of "Damping Off."

Zoösporangia or "conidia" globose to elliptic, usually papillate, 20–25 μ; gemmæ similar in form and size; oöspores globose, hyaline, smooth, 15–18 μ.



FIG. 47.—P. citriophora; development of swarmspores from sporangia. After Smith and Smith.

P. intermedium de Bary, causes a "damping off" of fern prothalia,[33] **P. gracile** Schenck, a rot of ginger; [38] **P. palmivorum** Butler, a palm disease in India.[36, 54]

Pithiacystis, Smith & Smith (p. 75)

The sporangiophore is delicate; septate; and bears numerous sporangia sympodially. These produce many biciliate zoöspores internally. No oöspores have been seen. Only one species is known.

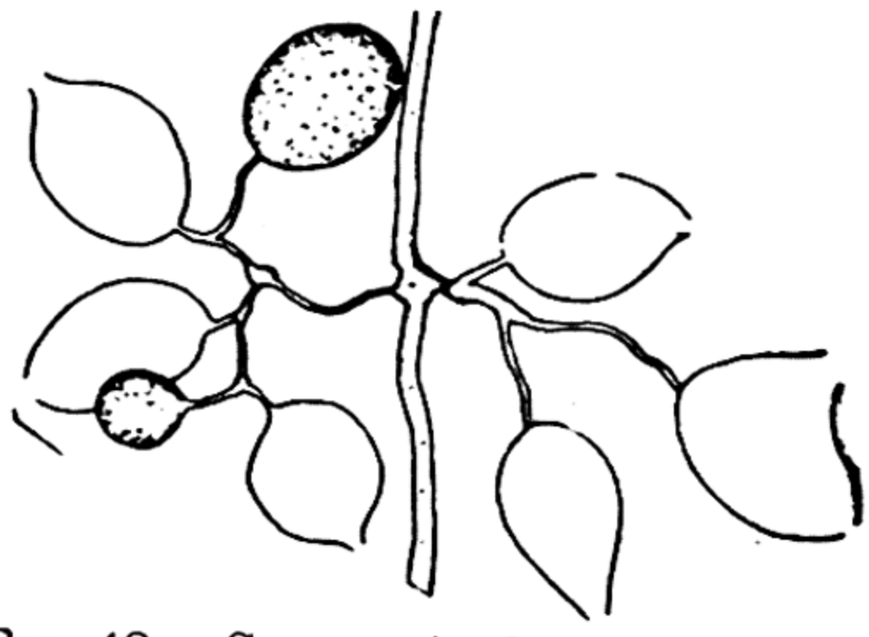


FIG. 48.—Sporangiophores and sporangia of Pythiacystis. After Smith and Smith.

P. citriophora Sm. & Sm.[39, 40]

Parasitic on lemons, the sterile mycelium inhabiting the rind; spores normally formed in the soil near infected fruits; sporangia ovate or lemon-shaped, papillate, 20–60 x 30–90 μ, averaging 35 x 50 μ, borne sympodially; zoöspores 10–16 μ, at first elongate, becoming rounded and bearing two lateral cilia.

This was first noted by Smith and Smith [39, 40] on rotting lemons in California. Infection by pure cultures proved that the fungus was the true cause of the rot.

Peronosporales (p. 66)

These fungi constitute an order characterized by a richly developed, branching, non-septate, usually coarse, mycelium of

strictly parasitic habit. The mycelial threads in most genera wander between the host cells and draw nutriment from them by short branches, sucking organs (**haustoria**), (Fig. 49) of various forms, which penetrate into the victimized cell. In one genus only, Phytophthora, does the mycelium grow directly through cells. Two kinds of spores are produced, sexual and asexual. The sexual spores result from the union of two unlike gametes, the egg (oösphere) and sperm, borne respectively in the oögonium and antheridium. Each oögonium bears a solitary oösphere. Fertilization is accomplished by means of a tube from the antheridium and penetrating into the oögonium. The sexual spores are thick walled, resistant, and usually require a long time to reach maturity. They are, therefore, often called "resting spores." In germinating the sexual spores produce either germ tubes or develop directly into zoösporangia. The asexual spores are conidia. They are borne on conidiophores which arise from the mycelium and which may be short or long, simple or branched, subepidermal or superficial according to the habit of the species. The conidia in various genera germinate by three methods, (1) a germ tube is sent out by the conidium, (2) the entire protoplasmic contents of the spore passes outside the spore wall and then forms a germ tube, or (3) the conidium by internal division breaks up into zoöspores.



FIG. 49.—Haustoria of a Peronospora. After Zopf.

KEY TO FAMILIES OF **Peronosporales**

Conidiophores, short, thick, subepidermal, conidia catenulate. . . . . 1. **Albuginaceæ,** p. 78.

Conidiophores, longer, superficial, simple or branched, conidia not catenulate. . . . . 2. **Peronosporaceæ,** p. 82.

Albuginaceæ

There is a single genus, **Albugo** (Persoon) Roussell. This genus of about fifteen species is entirely parasitic upon flowering plants,

causing the "white rusts." The conidia are borne in white blister-like sori under the raised and finally ruptured epidermis of the host. The conidiophores are short, club-shaped, arranged

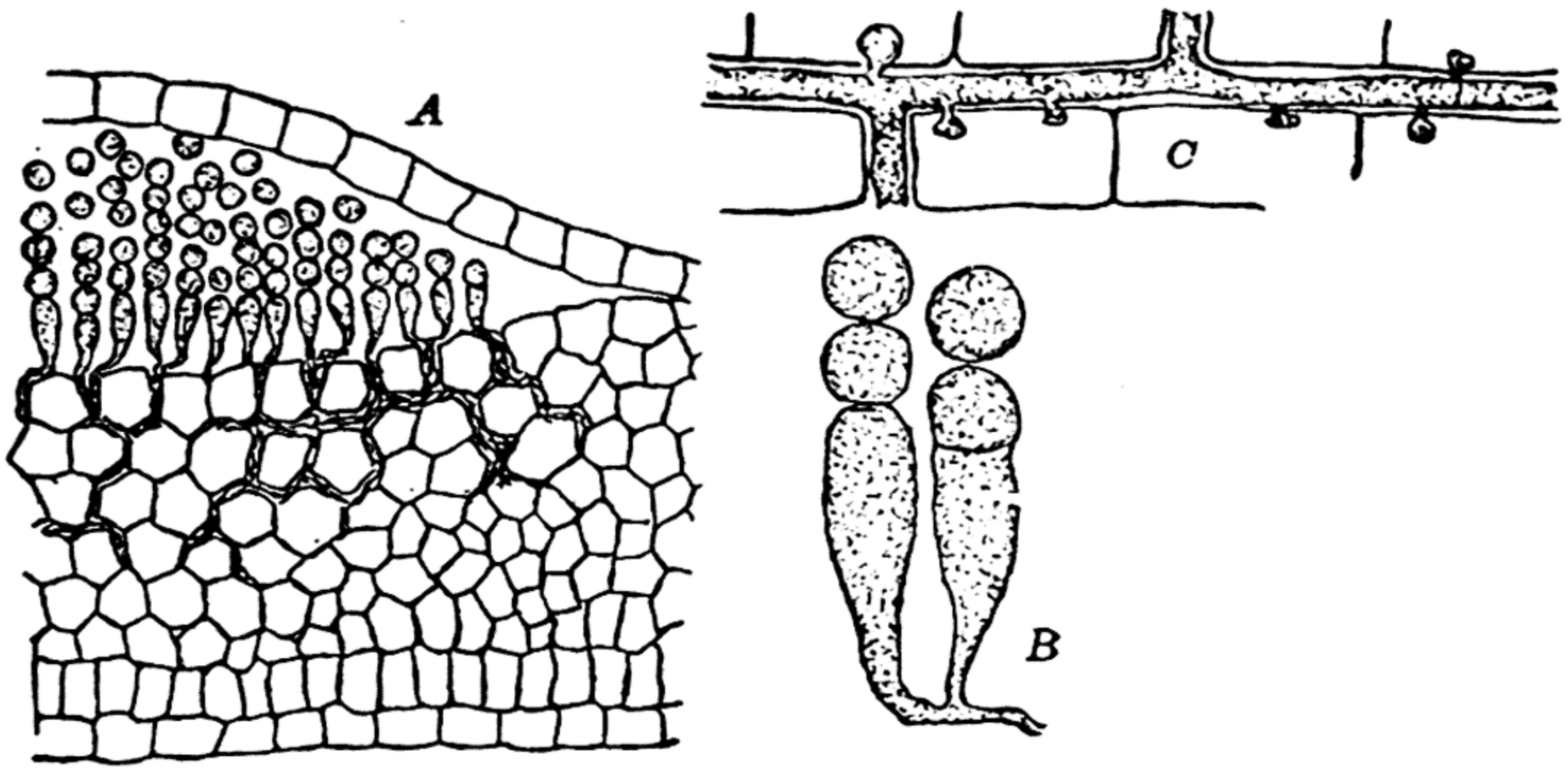


FIG. 50.—Albugo. *A*, section through a sorus showing epidermis, conidia, conidiophores and mycelium; *B*, conidiophores and conidia; *C*, mycelium and haustoria. After Bergen and Davis.

in clusters; the spores are borne in basipetal succession and remain attached in rather long chains unless disturbed.

The mycelium is very fine, intercellular and penetrates the cells by globular haustoria. The rudimentary oögonium is multinucleate and filled with uniform protoplasm. As the oögonium grows older the protoplasm within differentiates into two parts, the inner part of dense protoplasm, the oösphere, and the outer part less dense, the periplasm.[41] Figs. 51, 53, 54. During this process the nuclei enlarge, undergo one or two mitoses, Fig. 54, and in some species all the nuclei except one pass to the periplasm. In other species the oösphere is multinucleate at maturity. The latter type is fertilized by numerous nuclei from the antheridium, the former by a single nucleus.[41-44, 52] After fertilization the oösphere matures to an oöspore.

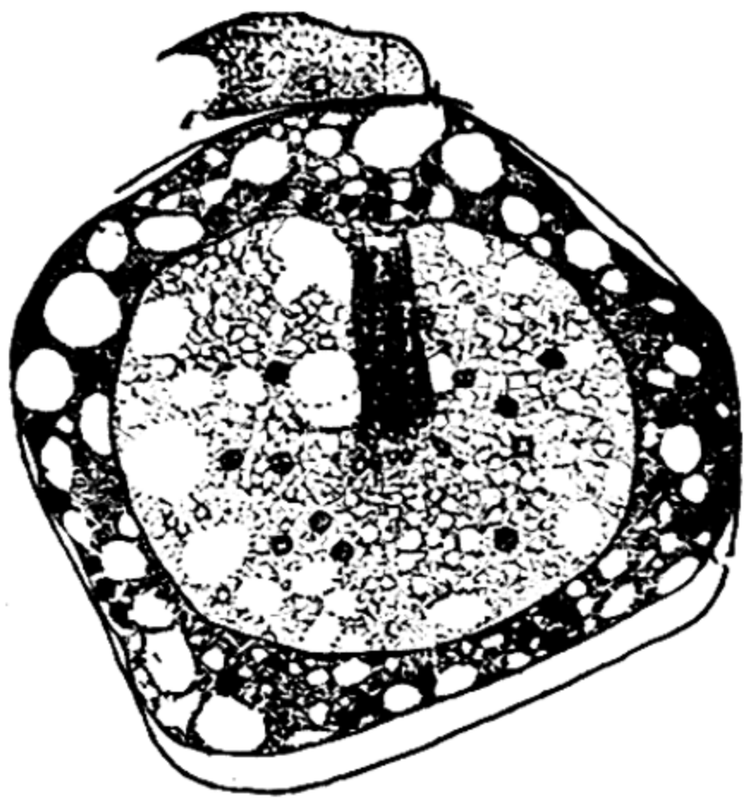


FIG. 51.—Multiple fertilization in A. bliti. Antheridial tube discharging sperms. After Stevens.

The globular oöspores fall into two classes;[45] first tuberculate or ridged; second, reticulated. These are illustrated in Fig. 52.

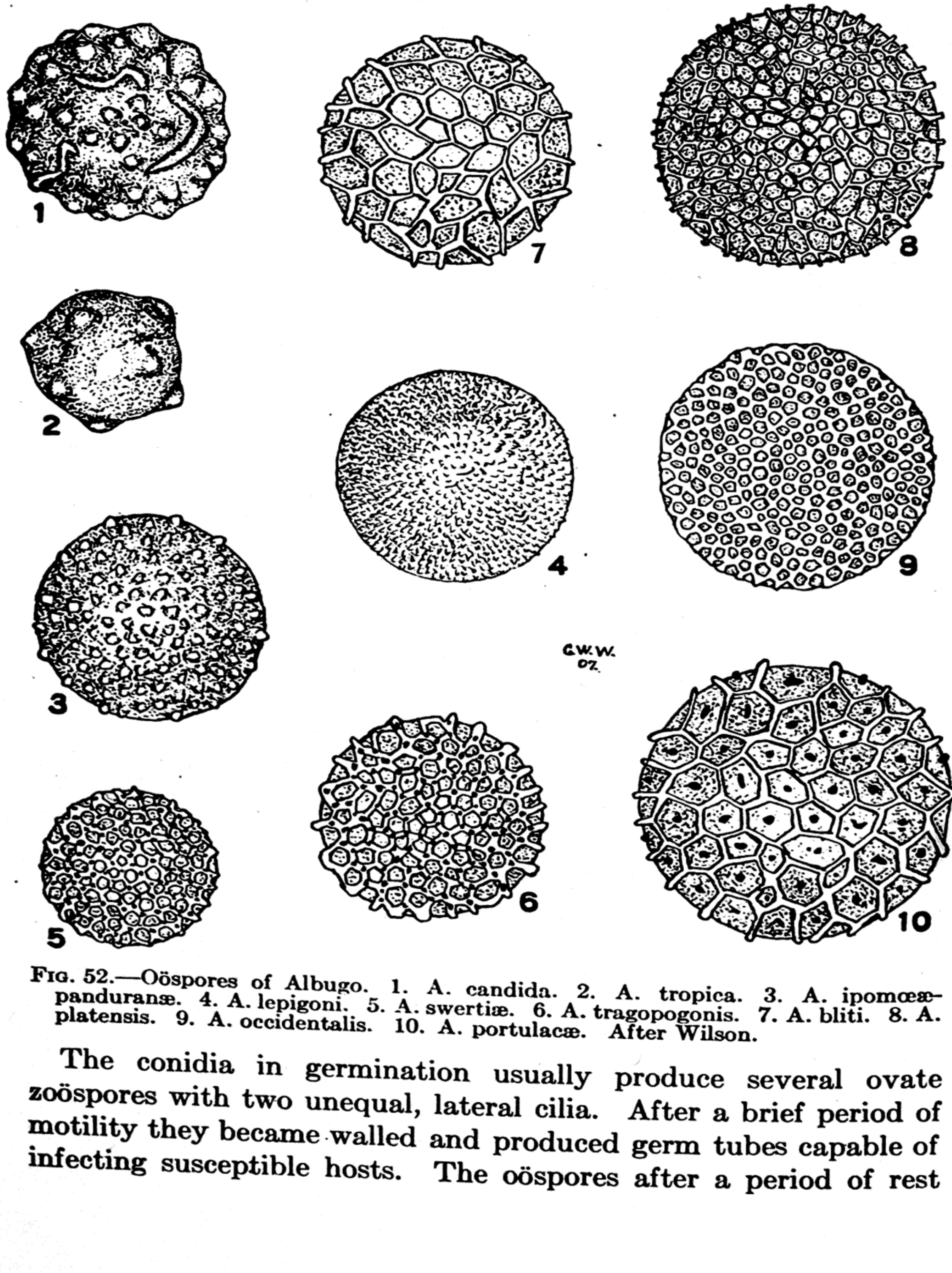


Fig. 52.—Oöspores of Albugo. 1. A. candida. 2. A. tropica. 3. A. ipomœæ-panduranæ. 4. A. lepigoni. 5. A. swertiæ. 6. A. tragopogonis. 7. A. bliti. 8. A. platensis. 9. A. occidentalis. 10. A. portulacæ. After Wilson.

The conidia in germination usually produce several ovate zoöspores with two unequal, lateral cilia. After a brief period of motility they became walled and produced germ tubes capable of infecting susceptible hosts. The oöspores after a period of rest

germinate in a similar manner. Conidia germinate freely only if they are chilled.[46]

A. candida (Pers.) Roussel.[47] Sori on all parts of the host except the roots, white or rarely light-yellow, prominent and rather deep-seated, variable in size and shape, often confluent and frequently producing marked distortion of the host; conidiophores hyaline, clavate, about 35–40 x 15–17 μ; conidia, globular, hyaline, with uniformly thin walls, 15–18 μ; oöspores, much less common than conidia, usually confined to stems and fruits, chocolate-colored,

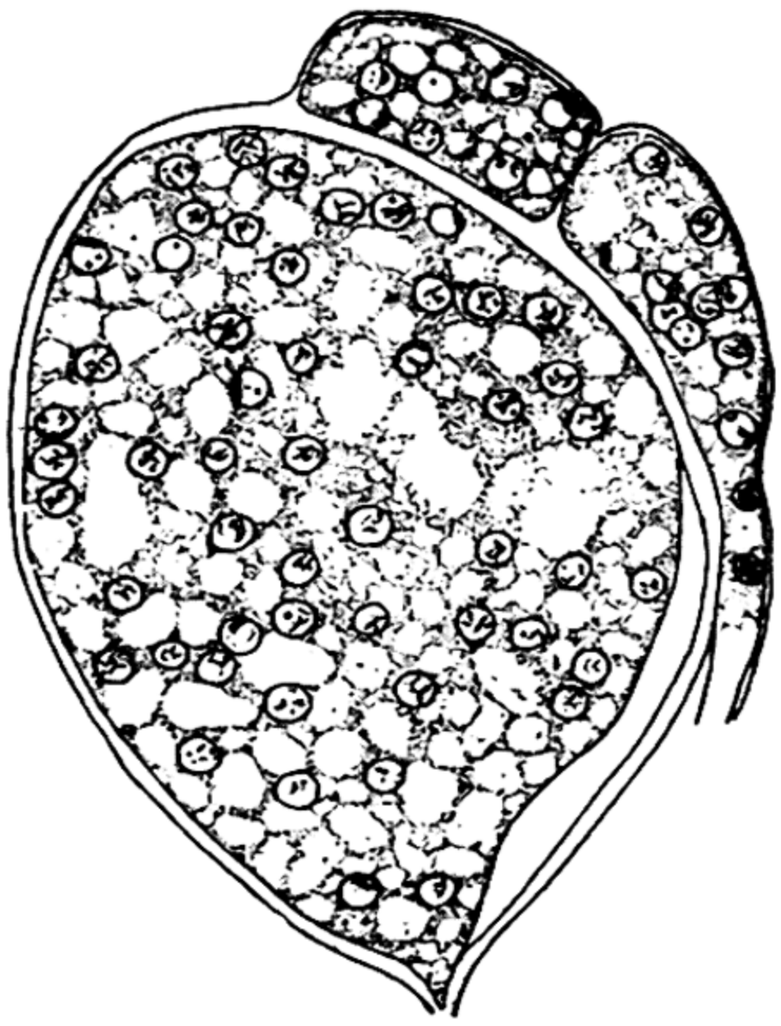


FIG. 53.—A. bliti, young oögonium and antheridium showing nuclei. After Stevens.



FIG. 54.—A. bliti, showing differentiation of oöplasm and periplasm, the nuclei in mitosis. After Stevens.



FIG. 55.—A. bliti, antheridium showing the multinucleate tube. After Stevens.

40–55 μ; epispore thick, verrucose, or with low blunt ridges which are often confluent and irregularly branched.

This is the most widely distributed and most common species of the genus. It occurs throughout the world on a large number of cruciferous hosts, and often gives rise to very pronounced hypertrophy. Practically all cultivated crucifers, cabbage, radish, turnip, etc., are subject to attacks of this fungus. In Europe the caper and mignonette are attacked by the same species. It has been reported in New York on Tropœolum.[48]

A. ipomœæ-panduranæ (Schw.) Sw.[49, 140] Sori amphigenous or caulicolous, white or light yellow, prominent, superficial, 0.5–20 mm., rounded, often confluent and frequently producing marked distortions of the host; conidiophores hyaline, clavate,

unequally curved at base, 15 x 30 μ; conidia hyaline; short-cylindric, all alike or the terminal more rounded, 14–20 x 12–18 μ; the membrane with an equatorial thickening, usually very pronounced. Oösporic sori separate from the conidial, caulicolous, rarely on petioles, 1–2 x 5–6 cm. or even more, causing marked distortion; oöspores light yellowish-brown, 25–55 μ; epispore papillate or with irregular, curved ridges.

Common throughout the world on various species of Convolvulaceæ, morning glory, moon flower, sweet potato, etc., although causing but little damage.

A. occidentalis G. W. W., reported by Pammel [50] on the beet has been collected but once.

A. portulaceæ (D. C.) Kze. on purslane [41] and **A. bliti** (Biv.) Kze.[42] occur on Amaranthus and related plants.

A. tragopogonis (D. C.) S. F. G.[51, 41] Sori hypophyllous or caulicolous, prominent, deep-seated, white or yellowish, pulverulent, rounded or elongate, 1–3 x 1–8 mm; conidiophores hyaline, clavate, about 12–15 x 40–50 μ; conidia, 12–15 x 18–22 μ; light yellow or hyaline, short-cylindric, the terminal larger and less angular than the others, membrane with an equatorial thickening; oöspores produced in stems and leaves, dark brown or almost black at maturity, opaque, 44–68 μ, epispore reticulate, areolæ 2 μ; wing bearing papillate tubercles at its angles.

A cosmopolitan species of less economic importance in America than in Europe attacking a wide range of hosts of the Compositæ. Salsify is the chief economic host.

Peronosporaceæ (p. 78)

The members of this family, producing the diseases commonly known as the "downy mildews," have been long known and much studied. They contain many important plant pathogens. The globular oöspores are in general indistinguishable from those of the Albuginaceæ but the conidiophores are quite different from those of that family, being aërial instead of subepidemal. In most cases they are branching and tree-like, Fig. 63, but in a few genera they are short. The oöspore in such genera as have been studied (Peronospora [52] Sclerospora [53]) is formed as in Albugo resulting when mature in an uninucleate egg surrounded by a

periplasm bearing the degenerate supernumerary nuclei. Fertilization is as in the Albugos that have an uninucleate egg.[41, 44, 52, 53]

The family has suffered many revisions of classification and much renaming of genera. Plasmopara and Peronospora are especially rich in a masquerade of names.[45, 54-57]

Key to Genera of Peronosporaceæ

Conidiophores scorpioid-cymosely branched; conidia germinating by zoöspores. . . . . 1. **Phytophthora,** p. 84.

Conidiophores simple, monopodially or dichotomously branched.

Conidiophores simple or monopodially branched; conidia germinating by zoöspores or by a plasma

Conidiophores simple or irregularly branched. . . . . 2. **Kawakamia,** p. 89.

Conidiophores regularly branched

Conidiophores with the main axis indurate, the lateral branches reduced and basidia-like. . . . . 3. **Basidiophora,** p. 89.

Conidiophores with the main axis not indurate, the lateral branches developed normally.

Conidiophores fugacious, stout, sparingly branched; oöspore permanently united to the wall of the oögonium. . . . . 4. **Sclerospora**, p. 89.

Conidiophores persistent, slender, usually freely branched; oöspore free from the wall of the oögonium

Branches of the conidiophore apically obtuse. . . . . 5. **Plasmopara,** p. 90.

Branches of the conidiophore apically acute. . . . . 6. **Peronoplasmopara,** p. 93

Conidiophores dichotomously branched; conidia germinating by a germ tube.

Conidiophores with subapical disk-like enlargements from which the ul-

timate branchlets arise radially; germ tube produced from the apex of the conidia. . . . . 7. **Bremia**, p. 95.

Conidiophores without subapical enlargements; conidia germinating from the side. . . . . 8. **Peronospora**, p. 95.

Phytophthora de Bary (p. 83)

This genus is of especial interest on account of its one exceedingly destructive representative, P. infestans, which occupies an historic position in phytopathology as one of the earliest of parasitic fungi to receive study in any way complete or adequate; study moreover which did much to turn attention and interest toward plant pathology.

A distinctive character is that the conidiophores have irregular thickenings below the apparently lateral conidia. The conidiophore is at first simple and bears a single apical conidium, after the production of which a lateral branch arises below the conidium and grows on in such a way as to give the first conidium a lateral appearance. This process is, in some species, repeated until a large scorpioid cyme is produced. The genus contains seven or eight species, all parasitic. The mycelium is much branched, non-septate, hyaline; the conidiophores arise singly or in groups from the stomata, or break through the epidermis; conidia oval, papillate; zoöspores oval, biciliate, escaping by rupture of the papilla; oöspores, when present, with the epispore more or less ridged.

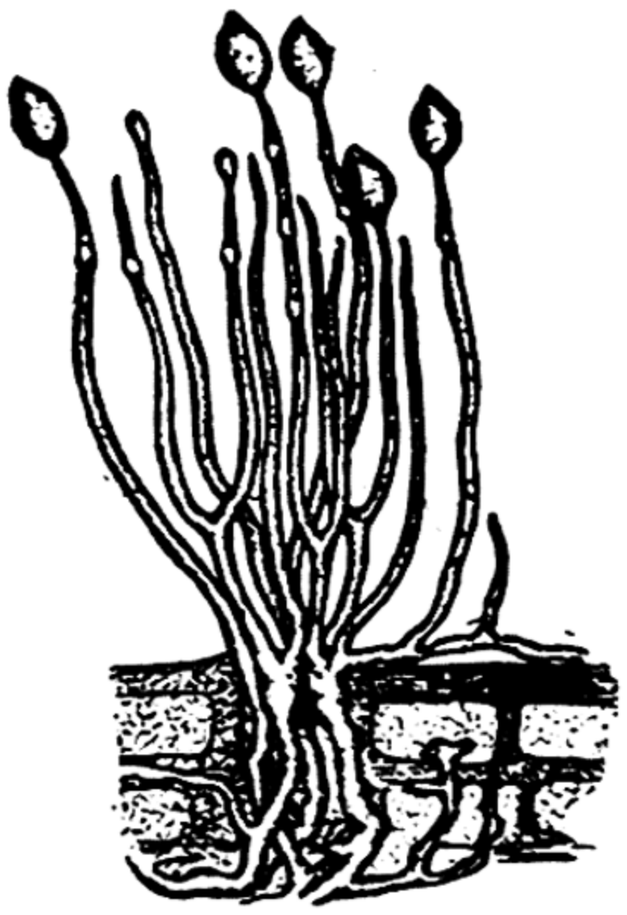


FIG. 56.—Structural details of P. phaseoli. After Thaxter.

P. phaseoli Thax.[58-61] Mycelium well developed, intracellular; conidiophores single or in clusters from the stomata, simple or branched below, apparently simple above but really one to many times cymosely branched; conidia oval or elliptic, papillate, 35–50 x 20–24 μ; germination by about fifteen zoöspores. Oögonia in the seed coats or cotyledons of seeds, rarely in the pods, thin walled, slightly folded; subspherical 23–28 μ; oöspores spherical or

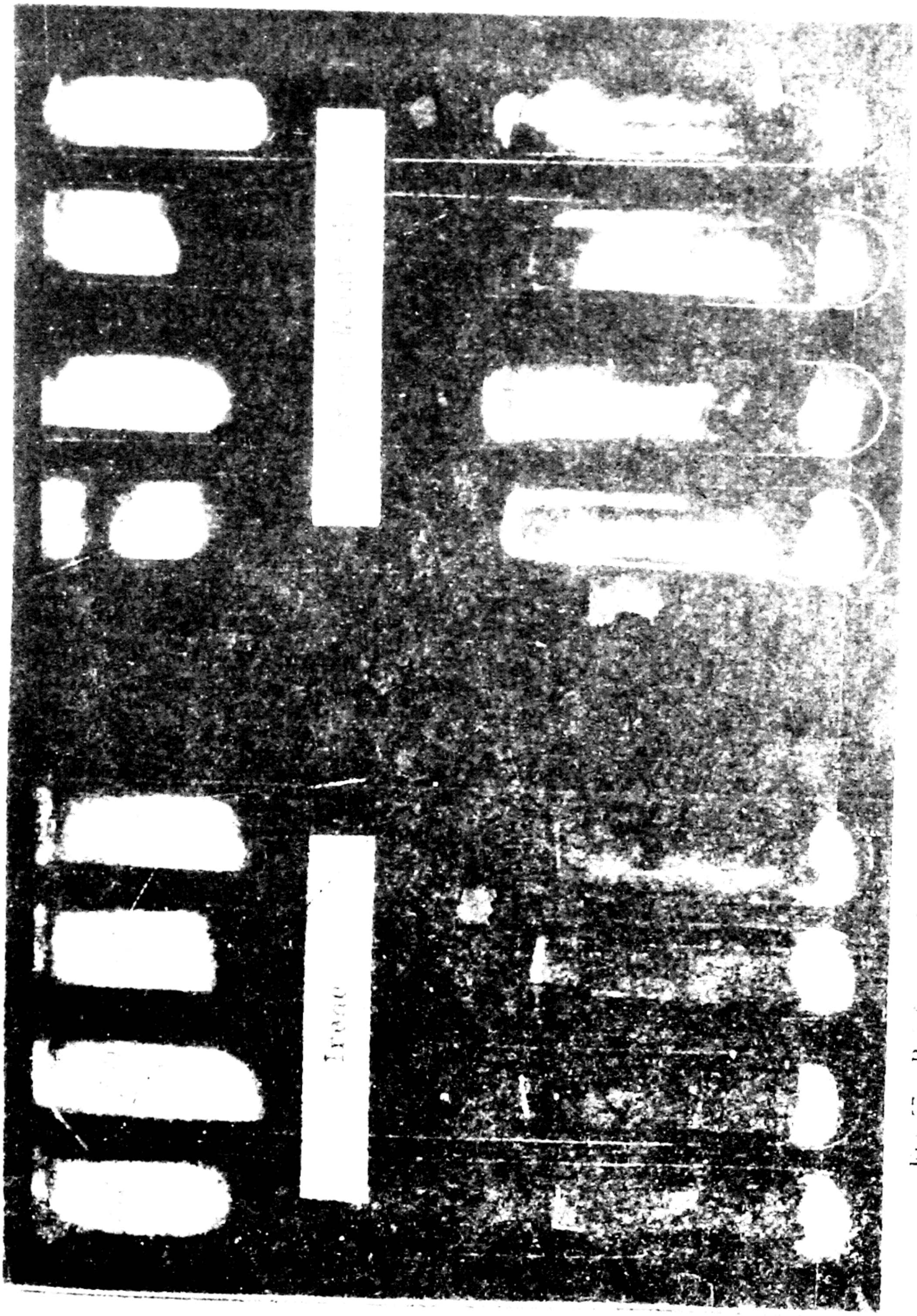


FIG. 57.—Potato plants, showing different stages of growth on two plots. After Jones.

subspherical with smooth, moderately thick walls, hyaline or light yellow, 18–26 μ. It was described on lima beans in 1889. The methods of infection were studied by Sturgis [62] who showed that spores are carried to the basal portion of the style and ovary by visiting insects. Oöspores were described and extensive artificial culture experiments made by Clinton [63] who first grew the fungus successfully in pure culture on corn-meal-agar, and other media, on which oöspores were produced in abundance.

The species is unique within the genus on account of the single conidia which are borne at the apex of apparently simple conidiophores but subtended by several enlargements of the kind so characteristic of the genus.

P. infestans (Mont.) de Bary.[64, 145, 146-148]

Mycelium well developed, probably perennial; conidiophores single or in groups of 2–4 from the stomata; scorpiose-cymosely branched; conidia 27–30 x 15–20 μ, ovoid, germinating by about six to sixteen zoöspores.

On diseased solanaceous hosts, particularly the potato and tomato,[64] this species is very destructive. It was first described in 1845 as a Botrytis and has since been the subject of many extensive papers.

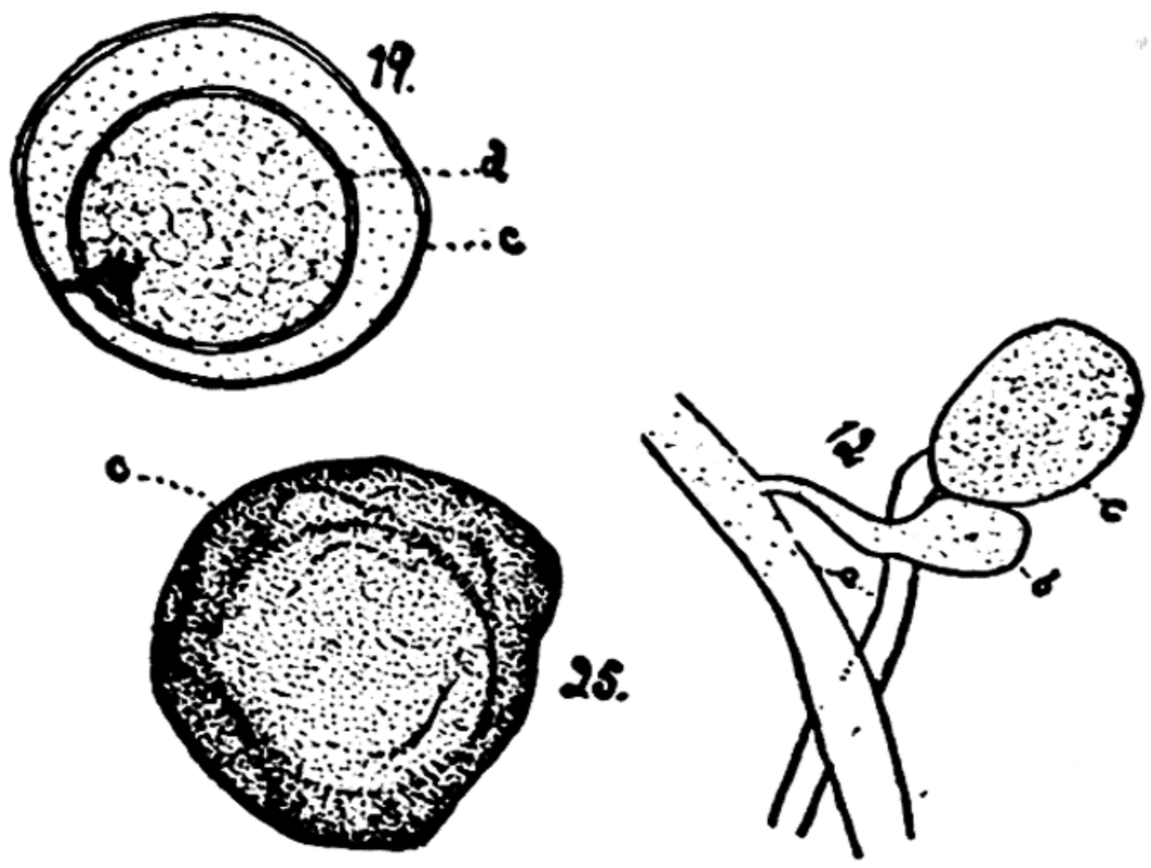


FIG. 58.—Young and mature oöspores of P. phaseoli. After Clinton.

The conidiophores are abundant on the lower sides of infected leaves near the invasion line. The mycelium migrates between the cells piercing them with haustoria.

The existence of oöspores is a much controverted point; the structures reported by Smith [65-67] as oöspores probably belonged to some other fungus. Recently Jones [68] found peculiar thick-walled bodies, somewhat resembling oöspores, in undoubtedly pure cultures of P. infestans. Whether they are oöspores is not known. Clinton has recently announced [69] that he, in pure cultures, has obtained "absolutely perfect oögonia, antheridia and even oöspores." The

oval, flattened biciliate zoöspores which emerge from the conidia, swim about, come to rest, develop a wall, then produce a germ tube. Direct germination by a germ tube also occurs rarely. In-

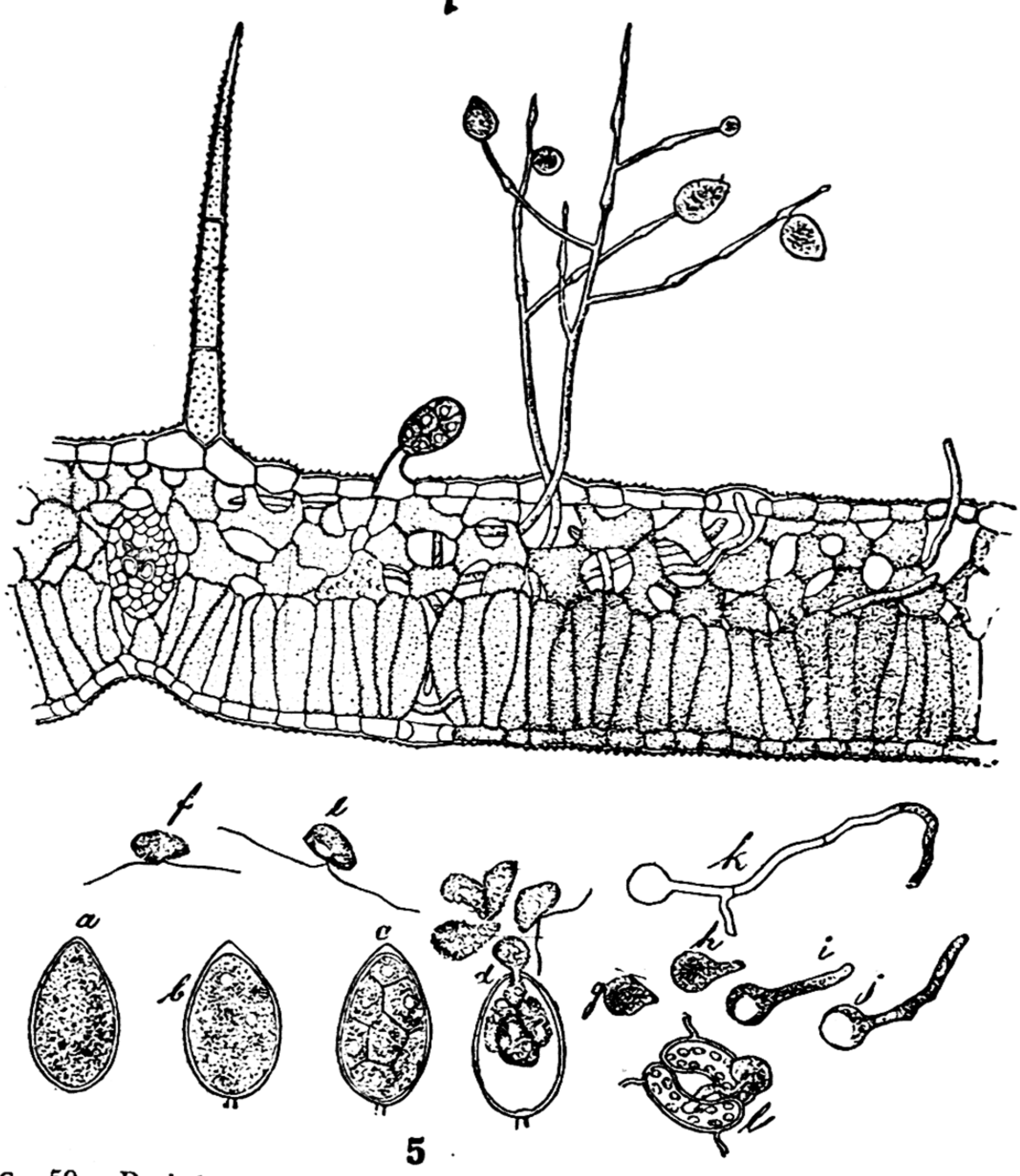


FIG. 59.—P. infestans; 1, section showing conidiophores and conidia-formation; 5, germination of a conidia. After Scribner.

fection is brought about by the germ tube, either by penetrating through stomata or directly through the epidermis.

The walls and contents of parasitized cells are browned. When this fungus is alone on the tubers dry rot is induced, but invasion of numerous saprophytic fungi and bacteria usually turns this into a disagreeable wet rot. Tuber infection occurs largely from

conidia washed into the soil by rain; possibly sometimes by the mycelium migrating by way of the stem.

The fungus was extensively studied by Jones in pure culture and a decided difference in luxuriance of growth was observed on blocks cut from different varieties of potatoes, Fig. 57.

The mode of hibernation is not thoroughly known but undoubtedly hibernation occurs in part in live mycelium in infected tubers.[70] The conidia are short-lived, especially when dry.

P. omnivora de Bary. Conidiophores simple or branched; conidia ovoid or lemon-shaped, 50–60 or even 90 x 35–40 μ, germinating by as many as fifty zoöspores; oöspores smoothish or wrinkled, light-brown, transparent, 24–30 μ. This species which includes forms previously described as P. cactorum (Lebert & Cohn) Schr., P. fagi Hartig, and P. sempervivi Schenk is found upon seedlings of some fifteen families ranging from Pinacæ to the higher Angiosperms. It is of considerable economic importance in Europe especially in the seed beds of the forester. Recently it has been found on ginseng in Japan and the United States.[71] The same fungus is credited with destructive rotting of apples[72] and pears[73] in Europe and with causing two wide-spread tropical diseases, the cocoa pod rot and a palm disease. From the studies of de Bary[74] and from the nature of the more recent outbreaks credited to this fungus it appears that P. omnivora is a composite species which will eventually be segregated. Indeed segregation has already been begun. Coleman[75] has described the palm infecting fungus of India as **P. omnivora** var. **arecæ** while Maublanc[76] has gone further and described the cocoa disease as **P. faberi.** See also [77, 78].

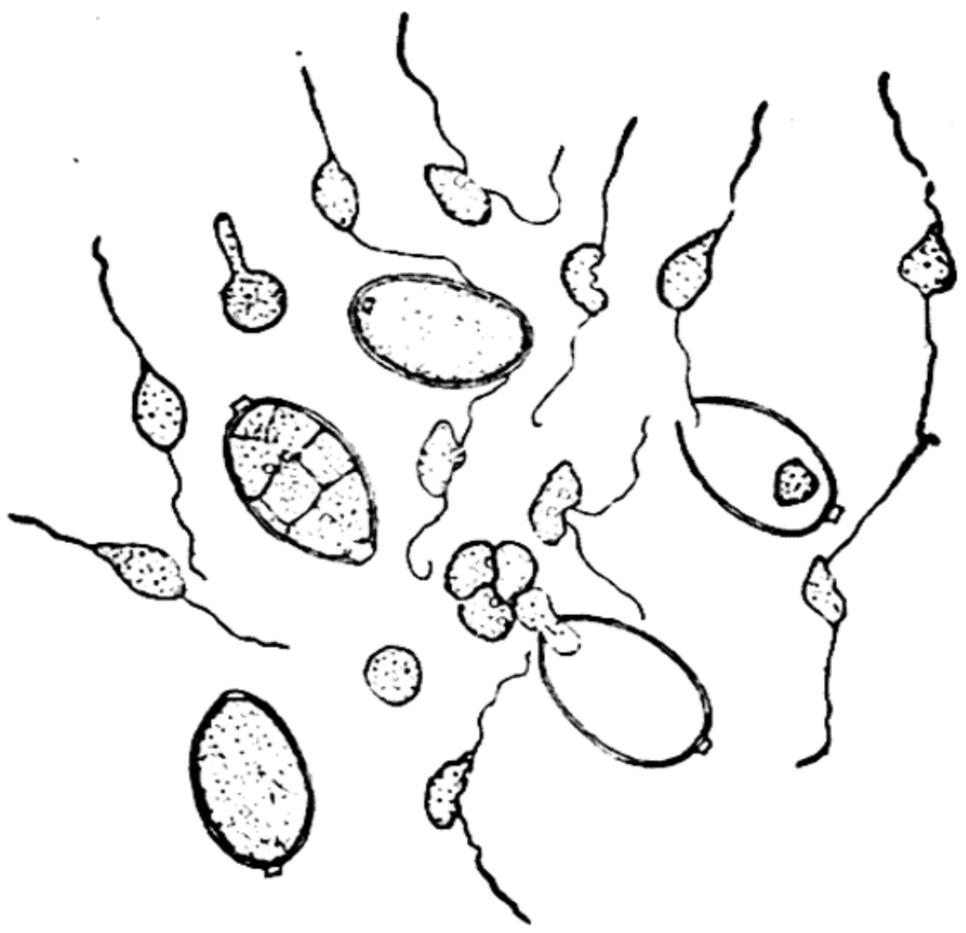


FIG. 60.—Formation of swarm-spore of Phytophthora. After Smith.

P. syringæ recently described by Klebahn is a closely related species, which is very destructive in the propagating beds of the lilac in Germany.

P. agaves Gan.[79] occurs on the Agave in Mexico.

P. nicotiana v. B. d H.[80] is also closely related to P. omnivora, but culture work shows it to be rather fastidious in its choice of host as it attacks only tobacco seedlings.

P. calocasiæ Rac. occurs on Calocasia antiquorum in the Orient. An undescribed species on Castor is also reported.[81]

Kawakamia Miyabi (p. 83)

Mycelium slender, copiously branched; conidiophores single or in groups of 2–5 or more from the stomata, simple or sometimes irregularly branched, but branches never arising near the conidia. Conidia usually upon a slender pedicel cell, lemon-shaped, obtusely tipped, contents and wall colorless, germination normally by zoöspores; zoöspores oval, flattened and laterally biciliate; oöspores spherical, smooth.

A single species, **K. cyperi** (M. & I.) Miyabe,[83] which was introduced from Japan into Texas in imported plants of a sedge, Cyperus tegetiformis. The species is very destructive in Japan. Both conidia and oöspores were produced in the Texan material.[82]

Basidiophora Roze & Cornu (p. 83)

B. entospora R. & C. occurs on species of Erigeron and cultivated aster in Europe and America.

Sclerospora Schröter (p. 83)

This genus differs from all other Peronosporales in the preponderance of its oöspores; these are the conspicuous stage, while the conidiophores and conidia are few, small and evanescent. There are about five species.

Mycelium much branched, with small vesicular haustoria; conidiophores erect, solitary or in groups of two or three, fugaceous, low and stocky, sparsely branched, the branches also stocky; conidia elliptic or globose-elliptic, hyaline, smooth; oöspores globose, intramycelial, the epispore brown, irregularly wrinkled, permanently united to the persistent wall of the oögonium.

S. graminicola (Sacc.) Schr.,[52, 53] infects leaves and inflorescences, the oöspores causing marked distortion of the latter and rapid disintegration of the former; conidiophores 100 x 10–12 μ, conidia 20 x 15–18 μ; oögonium wall thick, 4–12 μ, at maturity 30–60 μ in diameter, reddish-brown; oöspore pale-brown, 26–36 μ.

The conidial phase is not prominent, while the oöspores by their disintegrating effect upon the leaves of the host, render the plants quite conspicuous and closely simulate the habit of a brown smut.

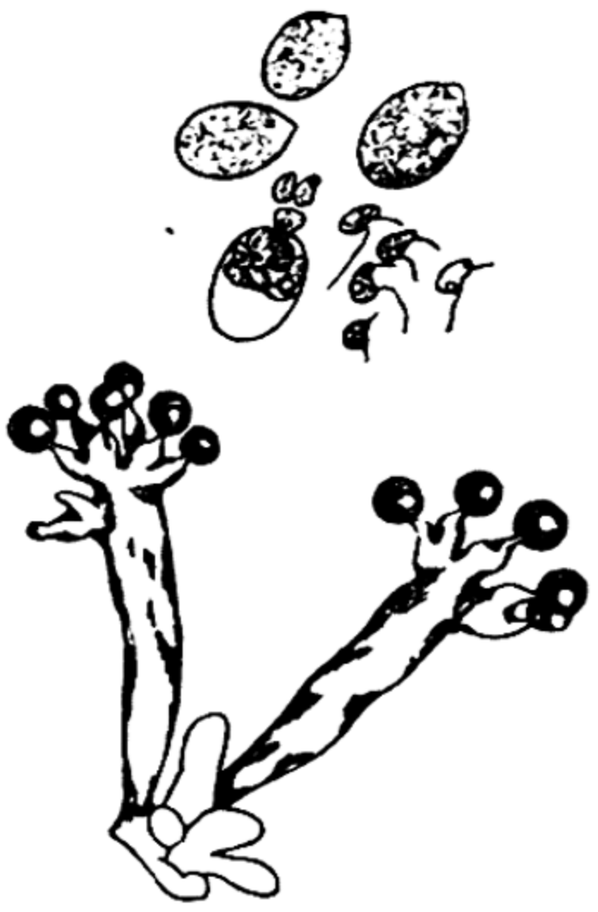


FIG. 61.—S. graminicola. Conidiophores and conidia; germinating conidia and zoöspores. After Butler.

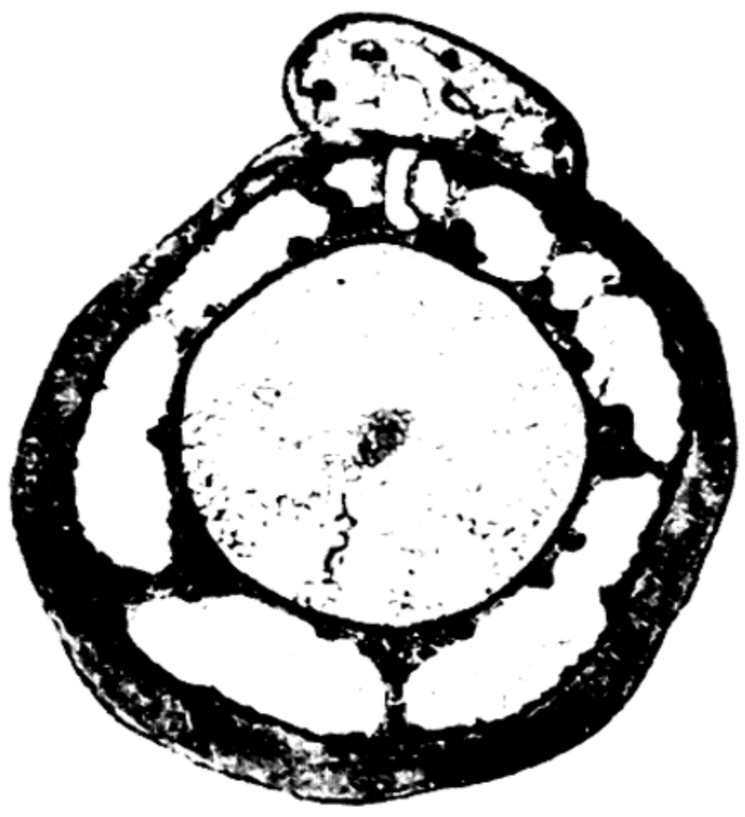


FIG. 62.—S. graminicola, oögonium, oöspore and antheridium in section. After Stevens.

On millet (Setaria italica), pearl millet, fox tail and corn; in India of considerable economic importance.[84]

S. macrospora Sacc. has been reported in corn tassels and on wheat in Italy and the United States.[85, 86] Conidia unknown; oögonia embedded firmly in the tissue of the host, not causing disintegration as in S. graminicola; oöspores light yellow, smooth, 60–65 μ.

Plasmopara. Schröter (p. 83) [134]

The tree-like, branching conidiophores, Fig. 63, are common to this genus, Peronospora, Peronoplasmopara and Bremia, and unlike the conidiophores of Phytophthora they are completely formed before they begin to bear spores.

Mycelium branched; haustoria simple; conidiophores erect,

solitary or fasciculate, from the stomata of the host, monopodially branched, the branches arising at right angles to the main axis, as do also the secondary branches (at least never appearing truly dichotomous) the ultimate branches apically obtuse; conidia globose to ovoid, hyaline or smoky, germinating by zoöspores or the entire protoplasmic mass escaping and then sending out a germ tube; oöspore globose yellowish-brown, the epispore variously wrinkled sometimes appearing somewhat reticulate; oögonium persistent, but free from the oöspore.

P. viticola (B. & C.) B. & d T.,[63, 88, 143, 144, 149] first collected in 1834 by Schweinitz and regarded as a Botrytis was first published in 1851.[87]

Hypophyllous, caulicolous, or on young fruits, covering the infected areas with a white downy growth; on the leaves epiphyllous discoloration yellowish; on the fruit often causing a brown rot without producing conidia; conidiophores fasciculate, 250–850 x 5–8 μ, 4–5 times branched, the ultimate branchlets about 8 μ long; conidia ovate-elliptic, very variable in size, 9–12 x 12–30 μ; oöspores 30–35 μ, epispore brown, wrinkled, or almost smooth; oögonium thin-walled, hyaline or light yellowish-brown.

The mycelium is found in all diseased tissues except the xylem. The conidiophores issue from stomata. The conidia germinate readily in water, producing in about three-fourths of an hour biciliate zoöspores. These after fifteen to twenty minutes activity cease motion, round off, become walled, then germinate by a tube. This bores through the epidermis and develops into the internal mycelium. Infection is almost exclusively from the lower side of the leaf.[89] Oöspores are much more rare than conidia but are often found in autumn, sometimes two hundred to a square millimeter of leaf surface. Though hibernation is doubtless chiefly by oöspores it has been shown that the mycelium can perennate in old wood, and even form oöspores therein. The fungus is dependent on abundant moisture.

P. nivea (Ung.) Schr. attacks various species of umbellifers including the parsnip and carrot. It has been reported in America only from the region of San Francisco.

P. halstedii (Farl.) B. & d T.

This form is quite variable and should perhaps be separated

into several distinct species. It is limited to the Compositæ, Helianthus and Madia being the only hosts of economic importance.

Hypophyllous; conidiophores fasciculate, slender, 300–750 μ, 3–5 times branched, ultimate branchlets 8–15 μ long, verticillate

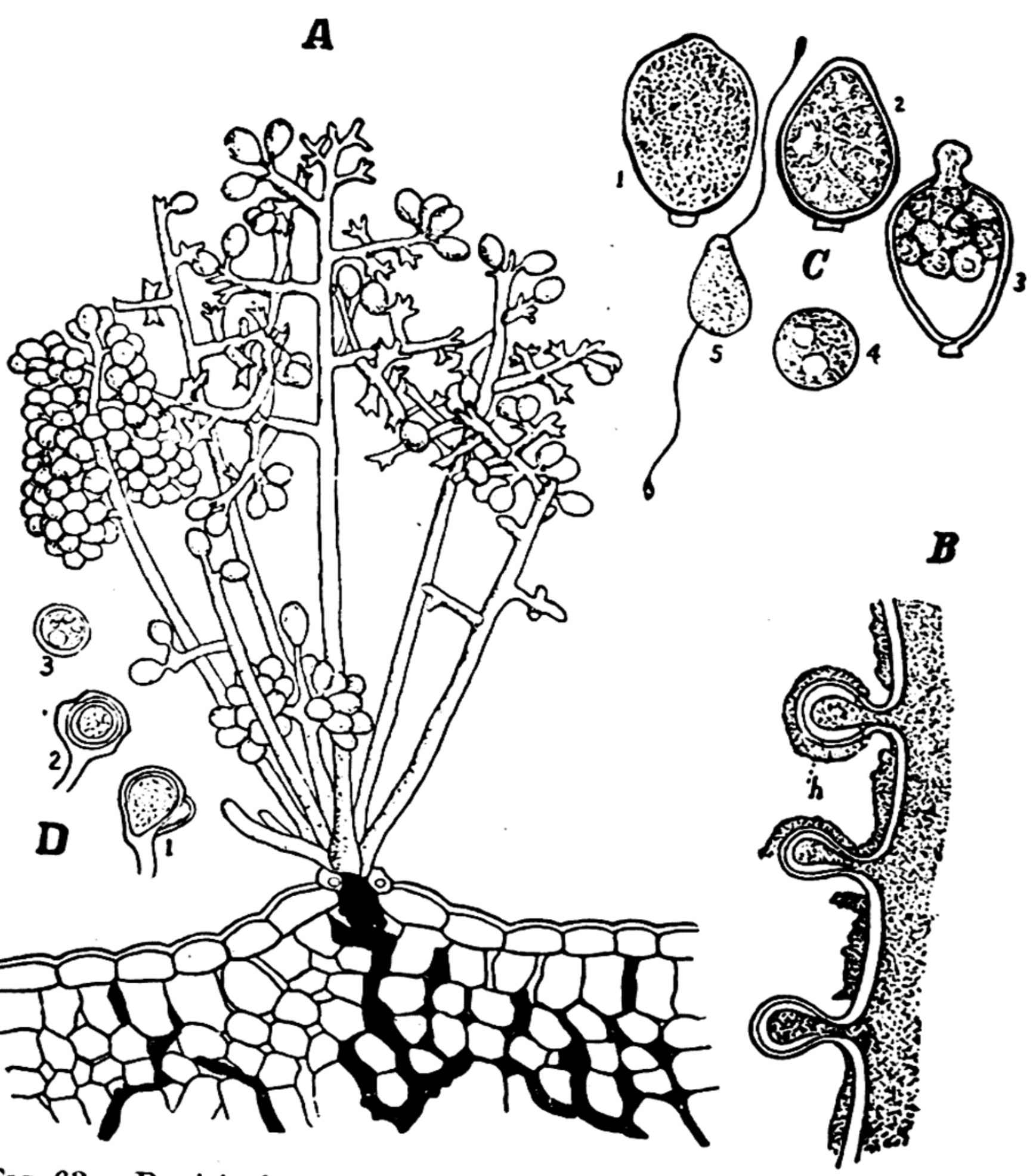


FIG. 63.—P. viticola. *A*, section of a leaf with conidiophores emerging from a stoma; *C*, formation of swarm spores; *D*, formation of oöspores. After Millardet.

below the apex of the branching axis which is frequently swollen and ganglion-like; conidia oval or elliptic, 18–30 x 14–25 μ; oöspores 30–32 μ, epispore yellowish-brown, somewhat wrinkled.

P. ribicola (Schr.) Schr. grows on various species of currants in Europe and America but is probably of but slight economic importance.

P. obducens (Schr.) Schr. occurs on Impatiens, both wild and cultivated, in North America, Europe and Asia.

P. pygmea (Ung.) Schr. on various Ranunculaceæ, including Aconitum in Europe and cultivated Hepaticas in America,[90] is of little economic importance.

Peronoplasmopara (Berlese) Clinton (p. 83)

There are three species which have been variously designated as Peronospora, Plasmopara, Pseudoplasmopara and Peronoplasmopara. The genus combines colored conidia and zoösporic germination with a type of conidiophores intermediate between those of Peronospora and Plasmopara.

Mycelium much branched, haustoria small, usually simple; conidiophores pseudo-monopodially branched, the ultimate branchlets acute, the primary arising at acute angles; conidia colored, elliptic, conspicuously papillate both apically and basally; oöspores thin-walled, smooth or roughened; oögonium thin-walled.

P. celtidis (Waite) Cl.[91] is unique in the family as the only species infecting dicotyledonous trees. It occurs on hackberry in the region about Chesapeake Bay, also in Japan.

P. humuli Miy. & Taka [92] causes a serious hop disease in Japan. It has recently been found by Davis [93] on wild hops in Wisconsin.

P. cubensis (B. & C.), Cl.[94-96, 102]

Hypophyllous, rarely amphigenous; discoloration of the host yellowish, or water-soaked; conidiophores 1–2 rarely more from a stoma, 180–400 x 5–9 μ, 3–4, rarely 2–5 times branched, the ultimate branchlets recurved; apically acute, 5–20 μ long; conidia gray, brownish or smoky, ovoid to ellipsoid, papillate, 20–40 x 14–25 μ; oöspores spherical, yellowish, warty-papillate, 30–43 μ, maturing in the decaying leaves.

The mycelium abounds in the spongy parenchyma. The conidiophores emerge through stomata, or rarely directly through the cuticle, near the invasion line of the fungus. Fresh conidia germinate in water in two to four hours forming flattish zoöspores with one anterior and one posterior cilium. The zoöspores later become spherical, walled and develop a germ tube. These germ tubes enter the host through the stomata or directly through the cuticle from either above or below. Moist weather is favorable to

the fungus in that conidia are produced more abundantly and retain their power of germination longer when moist. Disease spots appear two or three days after infection; conidia same nine or ten days after infection.

The species is perennial in Florida [97] and spreads northward as the season advances, reaching Ohio and New York by late summer

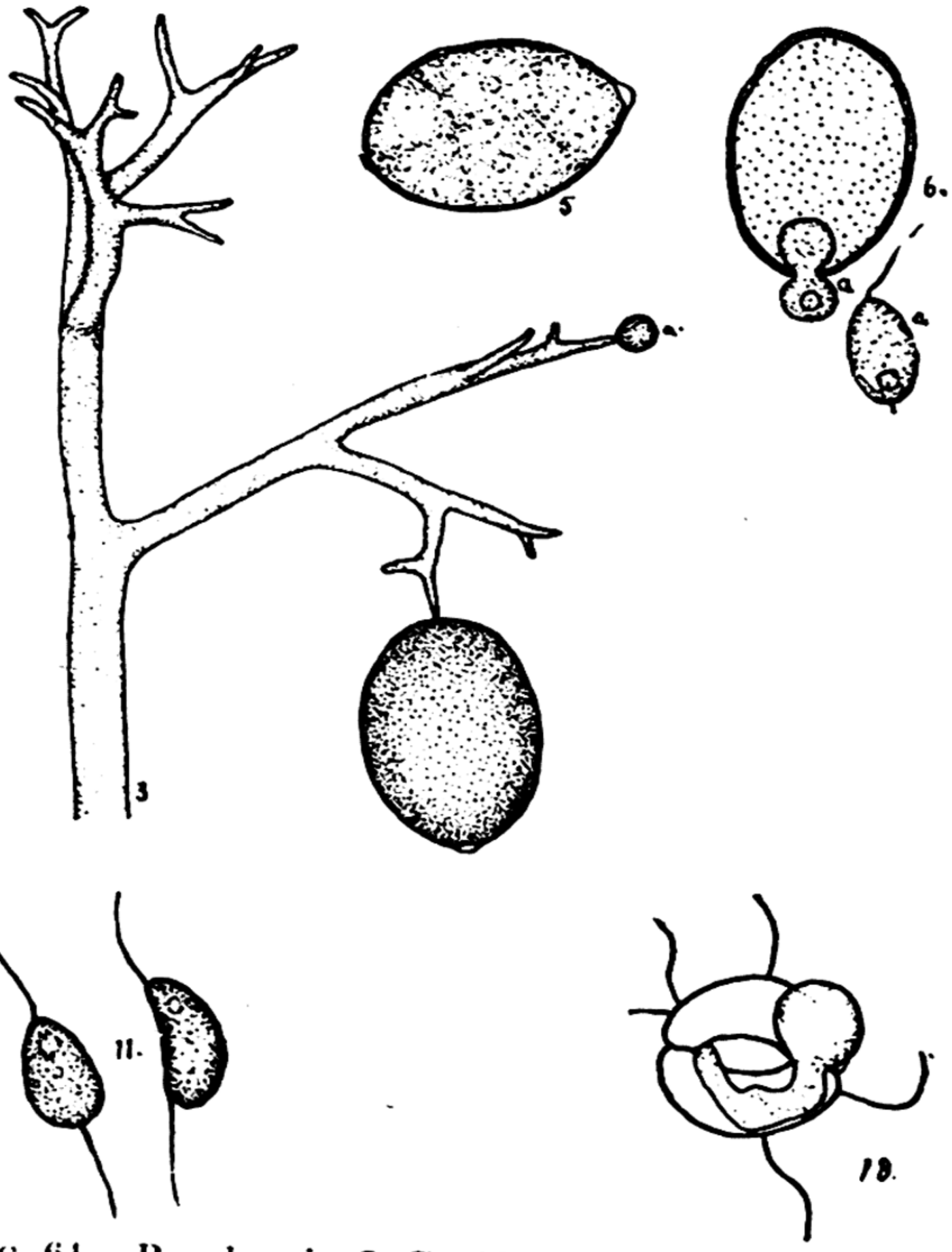


FIG. 64.—P. cubensis: 3. Conidiophore with young and old conidia. 5. Conidium. 6. Conidium germinating. 11. Zoöspores. 18. Infection through a stoma. After Clinton.

or early autumn.[98] For a series of years after its discovery it was not well known even scientifically, its first serious outbreak being about 1889.[99] It appeared in Japan about the same time [100] and is now known to be almost cosmopolitan. The oöspores have been found only by Rostewzew and have not been seen in America. A wide range of wild and cultivated cucurbits is infected, among

them the pumpkin, squash, cucumber, muskmelon, watermelon, gourd, in fact according to the work of Selby [101] any cucurbit appears liable to attack. Clinton infected muskmelons with spores produced on cucumber. The fungus is especially prevalent on cucumbers raised under glass.

Bremia Regel (p. 84)

As in Peronospora except that just below the ends of the conidiophore branches there are pronounced swellings from which spring radially a number of short branches each bearing an ovate, papillate conidium. The conidia germinate by apical germ tubes. There is only one species.



FIG. 65.—B. lactucæ. After Tubeuf.

B. lactucæ Regel is found on lettuce and several other Compositæ.[103] It is more injurious in Europe than in America.

Hypophyllous or amphigenous, causing discoloration, then wilting of the host; conidiophores produced singly but in great abundance, much branched; conidia ovate, 16–22 x 15–20 μ; oöspores small, 26–35 μ, light brown, the epispore wrinkled.

Peronospora Corda (p. 84) [52]

This genus of some sixty species contains several aggressive parasites. Its conidiophores are much like those of Plasmospara but with more tendency to dichotomous branching and to more graceful habit; the apices are acute.

Mycelium well developed, haustoria filiform, simple or branched; conidiophores dichotomously 2–10 times branched at acute angles, ultimate branchlets acute, more or less reflexed; conidia hyaline or colored, papillate, germinating directly by lateral germ tubes; oöspores globose, reticulate, tuberculate, wrinkled or smooth.

P. parasitica (Pers.) De Bary.[47] This is often associated with Albugo candida, giving it the appearance of a parasite on that fungus. Almost all species of Cruciferæ are subject to attack, among them cabbage, cauliflower, radish, collards, turnips, horse-

radish, and others of minor economic importance. It is cosmopolitan in distribution.

The fungus covers any green part of the host with a dense white growth, often causing hypertrophy especially in oöspore formation; conidiophores 200–300 x 10–12 μ, bushy branched, stout, deliquescent, with 5–8 main branches, each from 3–7 times branched, ultimate branchlets slender, more or less curved, usually arising at acute angles, about 12–15 x 2–3 μ; conidia broadly elliptic, bluntish, often becoming globose, about 12–22 x 24–27 μ, hyaline or very light; oöspore globose, yellow-brown, 26–45 μ, epispore smooth or wrinkled; oögonium thick, colorless.

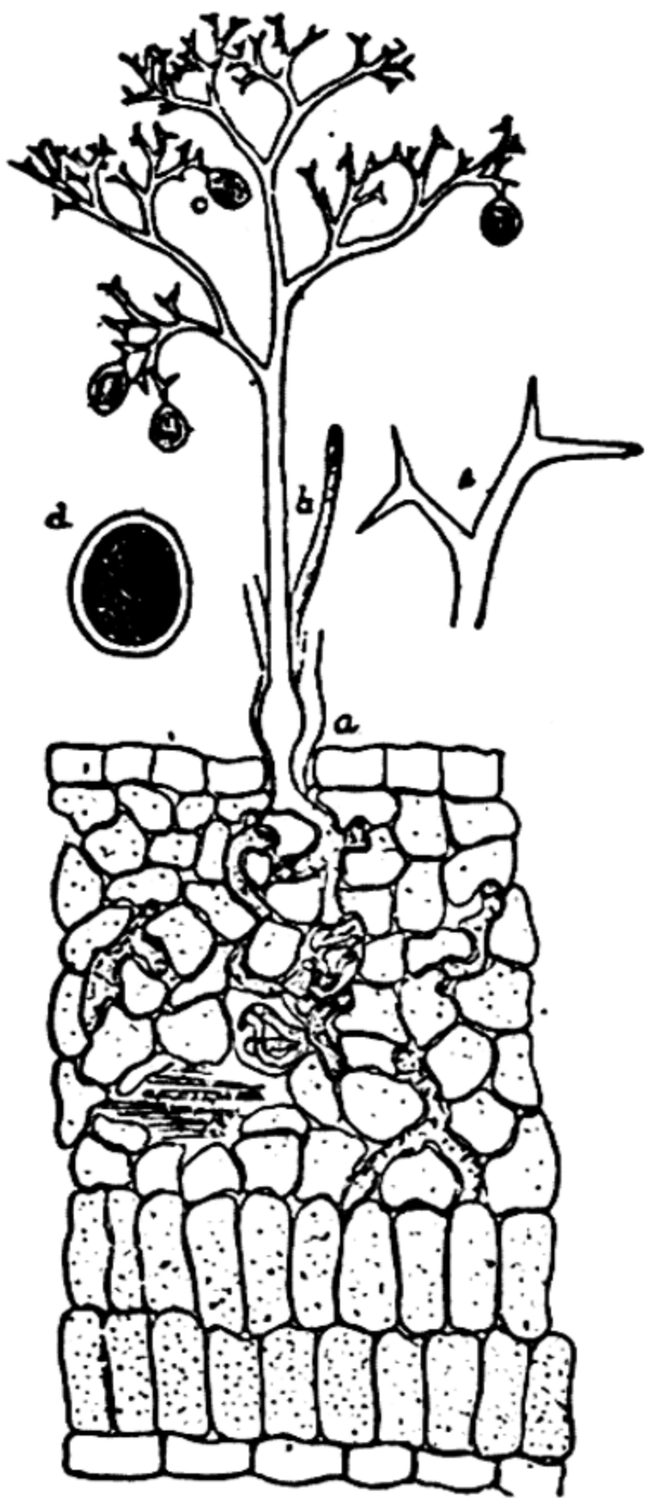


FIG. 66.—P. effusa on spinach. After Halsted.

P. effusa (Grev.) Rab. causes a serious disease of spinach.[104] It also occurs on a wide range of weeds of the Chenopodiaceæ. The species was formerly made to include all the effusæ forms of the genus so that literature abounds with references to it on Viola, Plantago, Polygonum, etc.

Hypophyllous, causing yellowish or brownish discolorations, the mass of conidiophores of a violet cast; conidiophores 150–400 x 7–9 μ, much branched, the ultimate branches at right angles, usually recurved, 8–15 x 3–4 μ; conidia ellipsoid to globose 17–18 x 22–24 μ, violet or smoky; oöspores globose, 30–40 μ, epispore light brown, more or less regularly wrinkled; oögonium thin, brown.

P. schleideni Ung.[105] was first described as a Botrytis in 1841. It was noted in America in 1872 by Taylor,[106] later by Trelease [107] and by many others.[108] A very complete description was given by Whetzel [105] in 1904 under the name P. schleideniana.

The conidia in mass present a purplish tint. The conidiophores usually emerge singly through the stomata. The slender, branched haustoria abound in the parasitized part often with their ends wrapped around the nuclei. In water the conidia

germinate directly to form an infective tube (Fig. 67) which grows into the stomata. According to Whetzel conidia retain their germinating power only a few hours. Shipley believed them viable for a much longer time.[109] Fertilization occurs much as in P. parasitica (Fig. 67) and the sexual spores, which abound, serve for hibernation. They may live several years.

It is found on onion, garlic, etc. (Allium sps.) everywhere, covering leaves with a dense growth; conidiophores, 3–6 times branched, 300–700 x 12–15 μ; branches 2–5, scattered, ultimate branchlets subulate, 15–20 μ, more or less recurved; conidia large, obovate to pyriform, basally papillate, 45–58 x 20–25 μ, the membrane violet; oöspore globose, light-brown, about 30 μ, epispore smooth or slightly wrinkled.

P. sparsa Berk. is parasitic on roses [37] and constitutes a serious pest in Europe, though not so common in America.

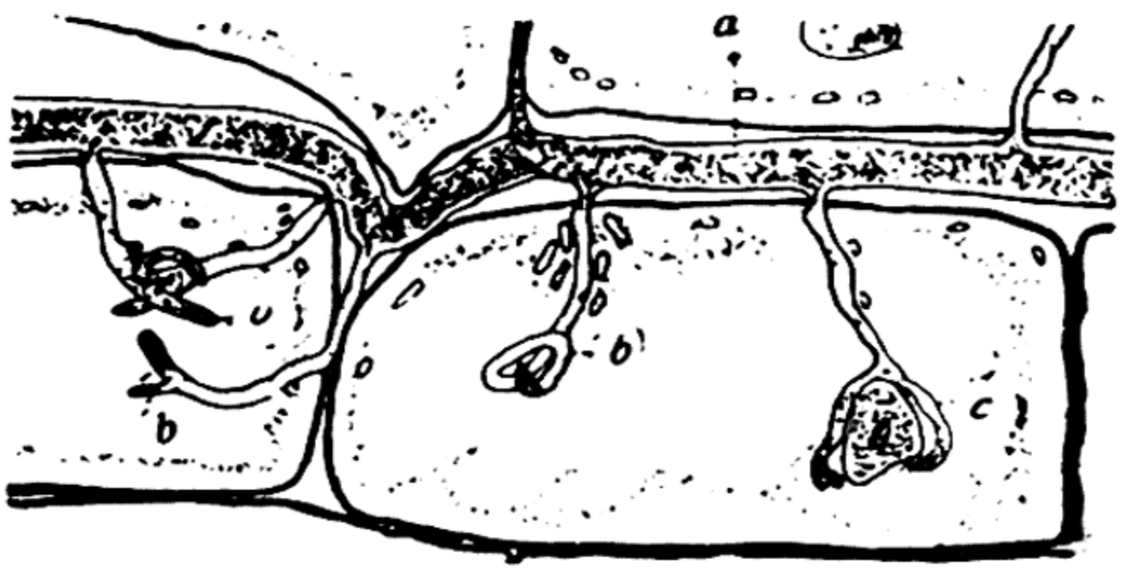
Hypophyllous, with a whitish growth; conidiophores about 9 times branched, the ultimate branchlets reflexed; conidia subelliptic, pale gray.

P. trifoliorum de Bary. Hypophyllous, forming a dense grayish or dirty-white growth over the host; conidiophores slender, 360–600 x 9–11 μ, 6–8 times branched at acute angles, the primary branches rather erect, the secondary more spreading, flexuose, more or less recurved, ultimate branchlets at right or obtuse angles, straight, subulate, 7–12 x 7–3 μ; conidia globose to broadly elliptic, 15–20 x 18–36 μ, violet; oöspores globose, 24–30 μ, epispore light brown, smooth.

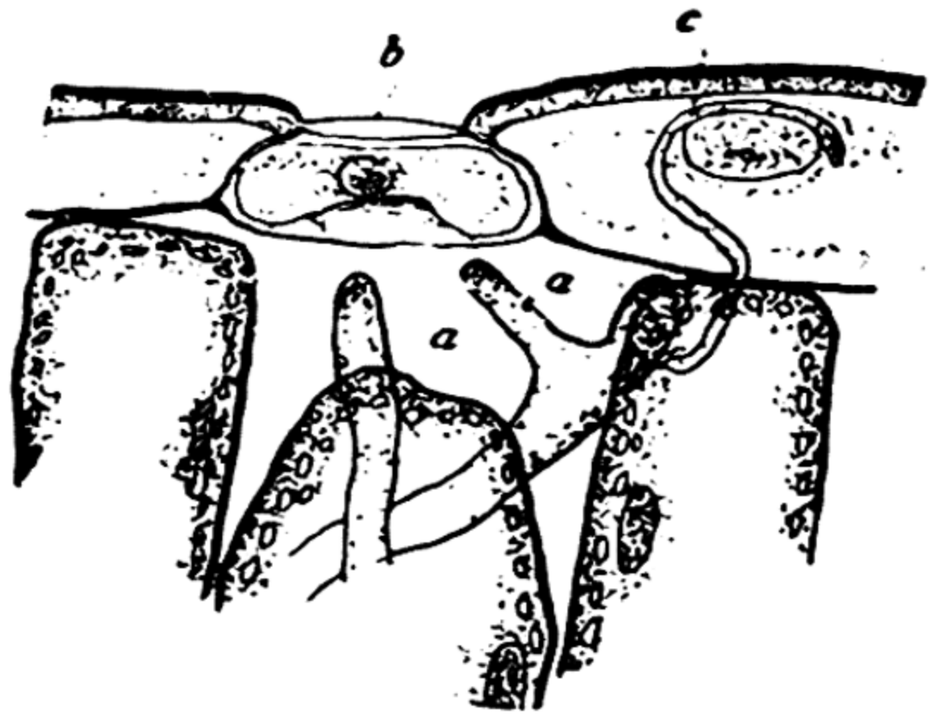
It causes serious loss to clover in Europe. Species of related genera also suffer. Recently it has assumed a rôle of importance in America by its attacks upon Alfalfa [110] on which it occurs from New York to California.

It differs from P. viciæ in the branching of the conidiophores, the lighter color of the spot and fungus, and the smooth oöspores.

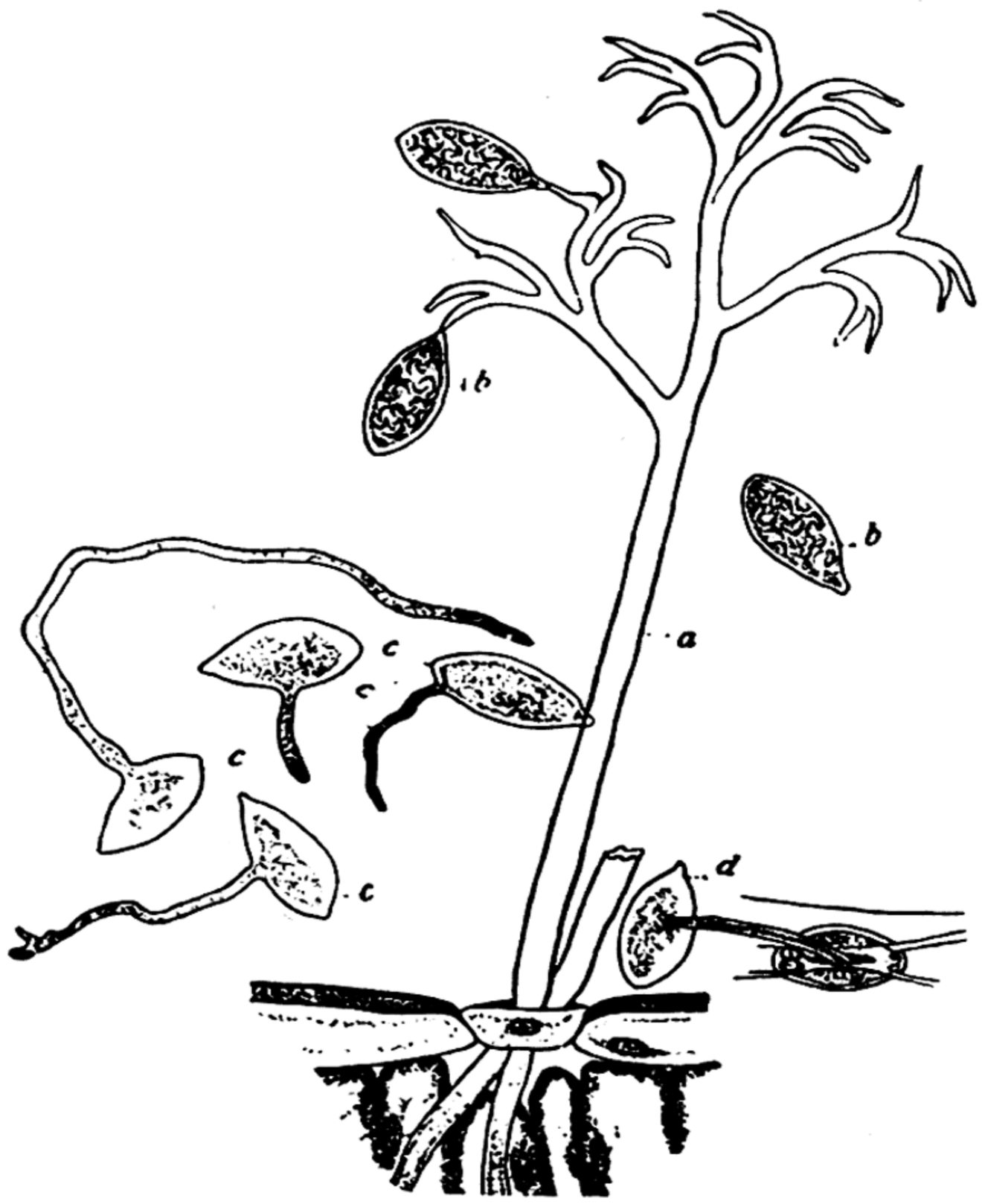
P. viciæ Berk. Hypophyllous or caulicolous, covering the host with a grayish-violet growth, epiphyllous discolorations yellowish or inconspicuous; conidiophores fasciculate, 300–700 x 9–11 μ, 5–8 times branched, the main branches arising at acute angles, erect, the ultimate subequal, slightly flexuose, arising at right or obtuse angles, the lateral recurved, 10–17 x 2–3 μ; conidia elliptic



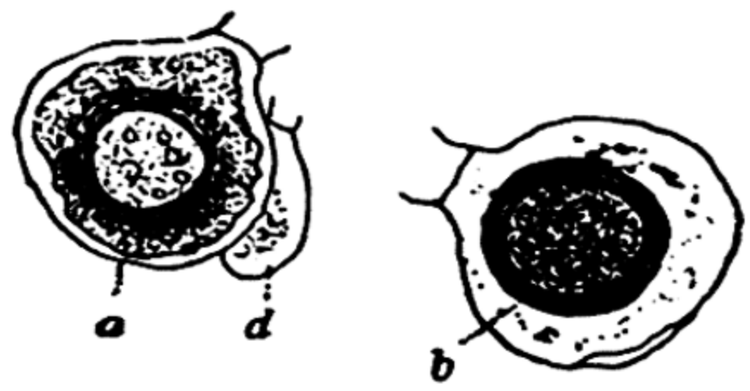
11



13



14



15

FIG. 67.—P. schleideni. 11. Mycelial threads between the large conductive cells of the leaf; (a) the mycelial thread; (b, b) branched or coiled haustoria; (c) branched haustorium wrapped about the nucleus. 13. Young conidiophores, (a, a) turning toward the stoma, (b); (c) haustorium wrapped about the nucleus of the epidermal cell. 14. Mature conidiophore (a) with mature conidia, (c, c); (d) germ tube of conidium entering stoma. 15. Oöspores, (a) mature oöspore with old antheridium, (d) still attached; (b) mature oöspore still inclosed in the old wall of the oögonium. After Whetzel.

or obovoid, 15–20 x 21–28 μ, light-violet; oöspores small, 25–30 μ, epispore yellowish-brown, with low, broad reticulations, areolæ about 8 μ; oögonium thin, fugaceous, 32–40 μ.

This fungus on Vicia and related genera is sometimes quite

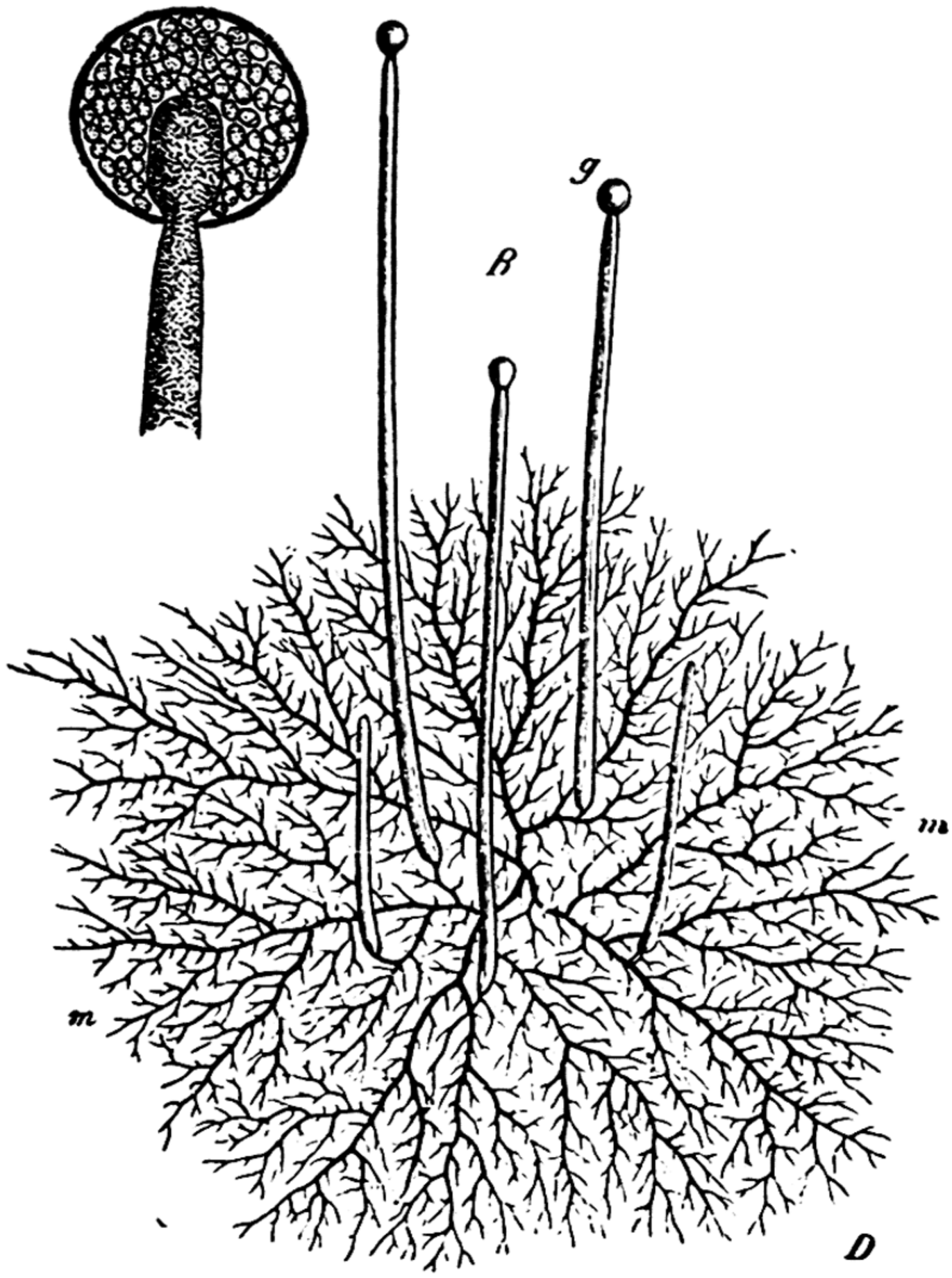


FIG. 68.—A sporangium with a columella (Mucor). After Sachs.

serious, particularly on vetch and peas in Europe, Asia and America.

P. violæ de Bary; on cultivated violets and the pansy in Europe and America,[47] forming discolored spots; foliicolous or caulicolous, with a pale violet growth, conidiophores fasciculate, short, 2–7 times dichotomously branched; ultimate branchlets short, subulate, reflexed; conidia elliptic, short, apiculate, 20–22 x 15–18 μ, violet.

P. dipsaci Tul. on teasel and Scabiosa in Europe and America and **P. violacea** Berk. on the flowers of species of Scabiosa in Europe are quite distinct from the preceding; **P. schachtii** Fcl. on beets kills seedlings in Europe. **P. linariæ** Fcl. is on digitalis; **P. cytisi**

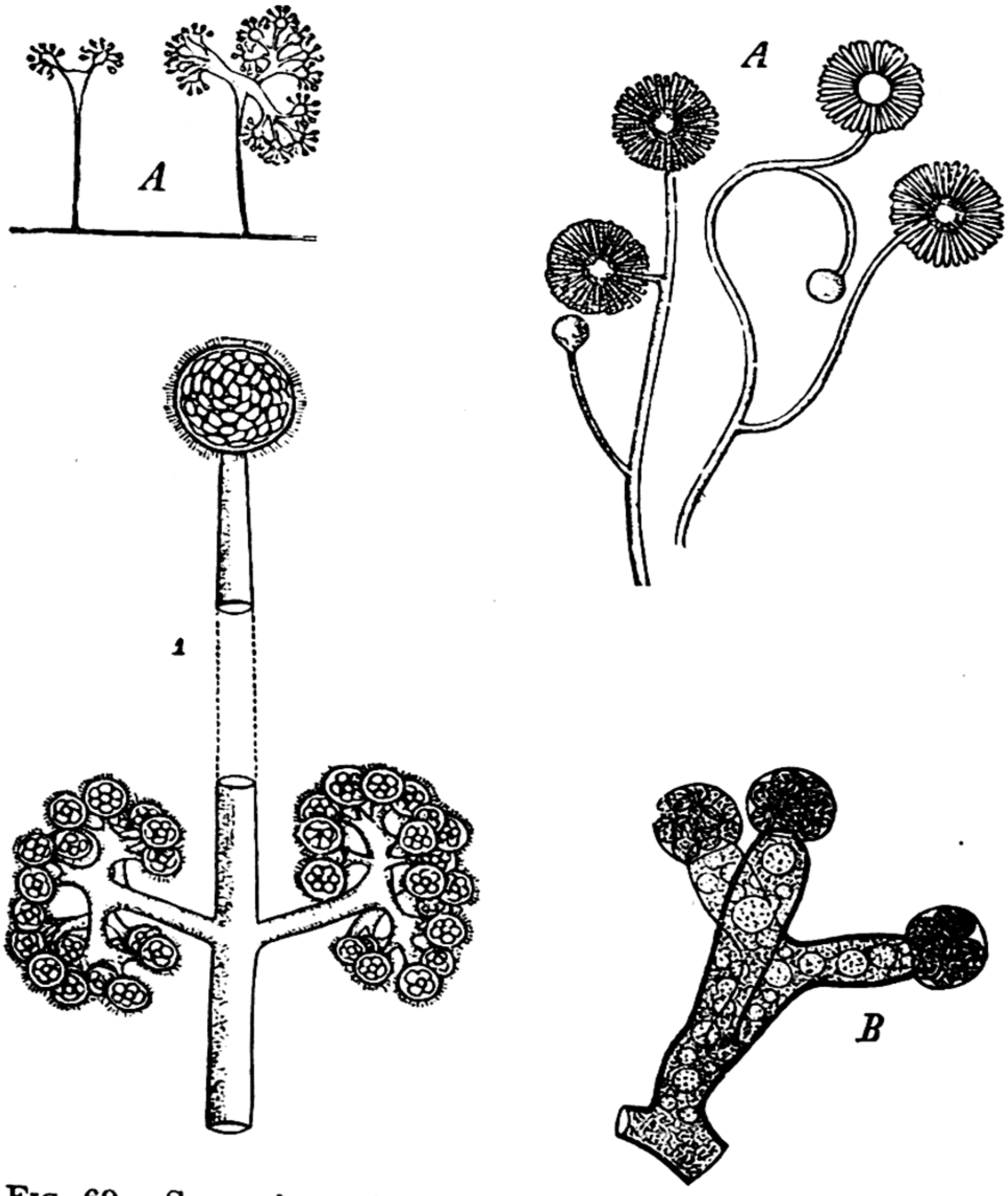


FIG. 69.—Sporophores in the Zygomycetes. After De Bary, Brefeld, Cunningham, Schröter.

Rost.[111, 112] on species of Cytisus in Europe; **P. arborescens** (Berk.) de Bary on poppies, especially garden seedlings, in Europe and Asia.

Species of less importance are:

P. rubi Rab. on various species of Rubus in Europe and America; **P. fragariæ** R. & C., usually cited as a synonym of P. potentillæ de Bary, on the strawberry in France and America; **P. trichomata** Mas.[113, 114] the cause of a root rot of Colocasia

in the West Indies; **P. candida** Fcl. on the primrose in Europe and upon non-economic Primulaceæ in America; **P. maydis** Rac.[115] the cause of a disease of corn in Java. [Its identity with Sclerospora graminicola is suggested by the recent studies of that species by Butler.] **P. vincæ** Schr. on Vinca minor in Europe; **P. myosotidis** de Bary on several species of forget-me-not and related genera in Europe and America; **P. cannabina** Otth. on hemp in Europe and Japan; **P. conglomerata** Fcl. upon alfilaria in Europe; **P. ficariæ** Tul. on various species of Ranunculus both in the old and the new world; **P. antirrhini** Schr. on the snapdragon and related hosts in Europe; **P. nicotianæ** Speg.[116] on various ornamental species of Nicotiana in South America and California; **P. valeria mellæ** Fcl. in Europe on Valerianella; **P. valerianæ** Trail on Valerian; **P. dianthi** de Bary on species of Dianthus in Europe; **P. corallæ** Tranz. on Campanula in Europe; **P. jaapiana** [117] on rhubarb in Europe; **P. phœnixæ** Tap. on Phœnix [118] and an undetermined species on Para rubber.

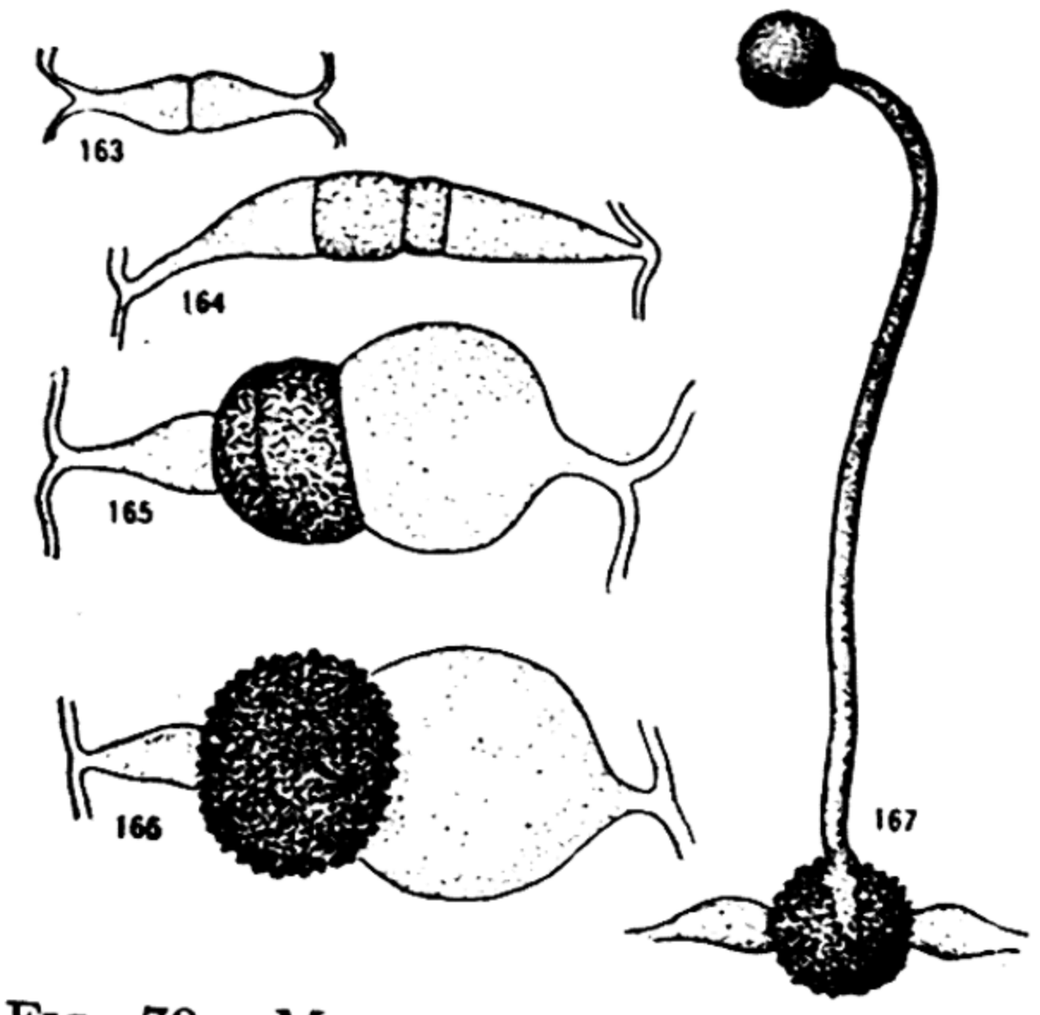


FIG. 70.—Mucor: zygospore formation. After Brefeld.

Mycelophagus castaneæ Man.[119] is an imperfectly described form which may belong either to the present group or to the Chytridiales. A serious disease of the chestnut in France is charged to it.

Zygomycetes (p. 66)

This group of fungi is readily distinguished from the Oömycetes by its isogamous sexual organs, when these are present. In the absence of sexual organs the general type of sporangium is usually sufficient mark of distinction for those who are even but slightly acquainted with the two groups. The mycelium, if young, serves to indicate relationship to the Phycomycetes. Older mycelium is often septate and would lead the unwary into errors of classification.

Asexual spores are either in sporangia or are borne as conidia. The sporangium is usually with a **columella**. The spore-bearing stalks exhibit the widest diversity in shape and form of branching, Fig. 69.

Sexual spores (**zygotes**) are produced through the union of two like gametangia. (Fig. 70.) Though the cytology of zygote formation has not been completely studied it seems clear that the fertilization is multi-nucleate [135] as in Albugo bliti and that the two uniting elements are cœnogametes.

Key to Orders of **Zygomycetes**

Asexual spores borne in sporangia which in some genera are reduced to conidia-like bodies.	1. **Mucorales,** p. 102.
Asexual spores true conidia borne singly at the apex of the conidiophores. . . .	2. **Entomophthorales,** p. 107.

Mucorales (p. 66)

This order is comprised mainly of saprophytes, about twenty genera and one hundred fifty species; but includes a few forms which prey upon vegetation in a very low ebb of life, as cells of ripe fruit, tubers, etc., and a few species which are of especial interest as they grow upon other fungi. The sporangial stage is exceedingly common; the zygosporic much less so, very rare in the case of some species. Blakeslee [120] has shown that in some species, though the two uniting sexual organs are to all appearances alike, the plants are in reality dicœcious; that a branch from one plant cannot produce sexual organs that will unite with other sexual organs produced upon the same plant. Moreover, there appears to be a differentiation of sex in that one plant, which may provisionally be re-

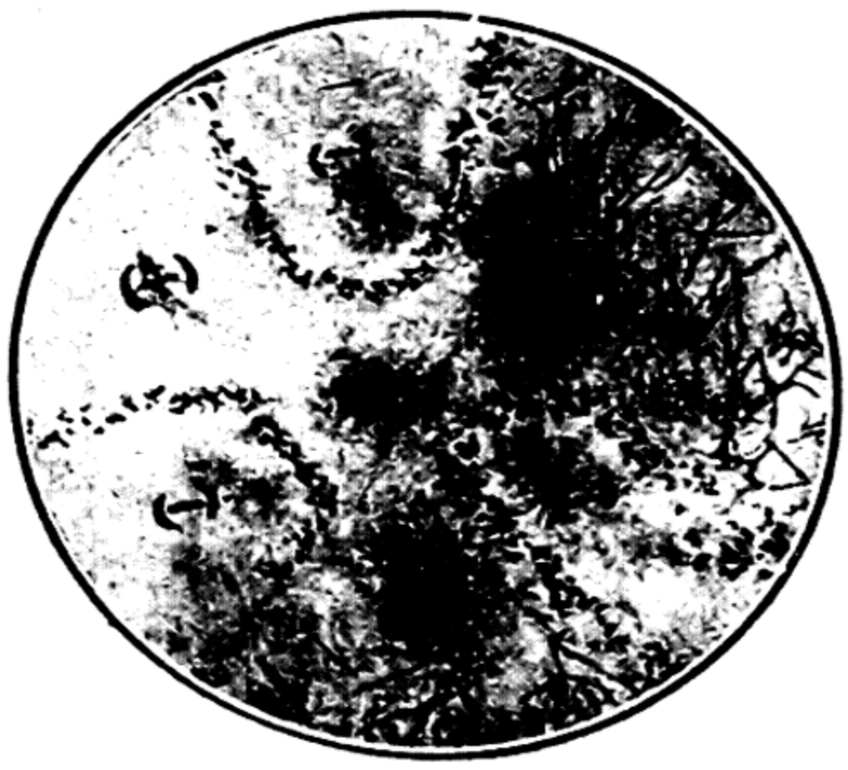


Fig. 71.—Phycomycetes showing zygosporic lines at regions of contact between + and — strains. After Blakeslee.

garded as the male, unites freely with another plant, provisionally the female, but this male plant refuses to unite with any other plant which is capable of uniting with the female, and all plants that can unite with the male refuse to unite with the females. In some species the plants of one sex show a more luxuriant vegetative growth than do plants of the other sex.

Key to Families of Mucorales.

Asexual spores in typical sporangia, although in some genera few-spored	
Sporangium with columella; zygospores naked or thinly covered with outgrowths of the suspensor	1. **Mucoraceæ,** p. 103.
Sporangium without a columella; zygospores closely covered by hyphæ	2. **Mortierellaceæ.**
Asexual sporangia monosporic and conidia-like, sometimes accompanied by larger polysporic sporangia	
Sporangia of two kinds, polysporic and monosporic	3. **Choanephoraceæ,** p. 106.
Sporangia all monosporic; parasitic on other genera of Mucorales	4. **Chætocladiaceæ.**
Sporangia simulating chains of conidia	5. **Piptocephalidaceæ.**

Of these families the second and fifth are pure saprophytes, while the fourth is parasitic upon other members of the order.

Mucoraceæ

Mycelial threads all alike or of two kinds, one aërial, the other buried in the substratum, cœnocytic during growth but septate at maturity; reproduction by asexual spores borne in sporangia and by zygospores formed by the union of equal gametes; sporangiophores, simple or branched; sporangia variable, typically with a columella, and many spores but in some genera some of the sporangia are few-spored and without columellas; zygospores variable, smooth or spiny, borne on short branches of the mycelium.

KEY TO SUBFAMILIES AND GENERA OF **Mucoraceæ**

Sporangial membrane cuticularized and permanent above, thin and fugaceous below..... Subfamily I. **Piloboleæ.**
Sporangiophore of equal size throughout; spore mass not forcibly discharged... **Pilaira.**
Sporangiophore swollen beneath the sporangium; spore mass forcibly discharged at maturity..... **Pilobolus, p. 105.**
Sporangial membrane thin and fugaceous throughout
Sporangia all similar..... Subfamily II. **Mucoreæ.**
Mycelium differentiated into a colorless vegetative and a colored aërial region
Aërial mycelium stoloniferous, zygospores formed in the substratum
Sporangiophores arising from the nodes..... 1. **Rhizopus, p. 105.**
Sporangiophores arising from the internodes..... 2. **Absidia.**
Aërial mycelium not stoloniferous; zygospores aërial
Sporangiophores simple ..... 3. **Spinellus.**
Sporangiophores dichotomously branched..... 4. **Syzygites.**
Mycelium undifferentiated
Mycelium gray or brown; suspensors smooth
Sporangiophores simple ..... 5. **Mucor, p. 106.**
Sporangiophores variously branched
Sporangia borne apically on the sporangiophore and its branches
Zygospores formed from equal gametes..... 6. **Calyptromyces.**
Zygospores formed from unequal gametes..... 7. **Zygorhynchus.**
Sporangia borne only on the lateral, circinate branches of the sporangiophore

Sporangia globular; columella not constricted.	8. **Circinella.**
Sporangia pear-shaped; columella constricted.....	9. **Pirella.**
Mycelium metallic; suspensors spiny	10. **Phycomyces.**
Sporangia of two kinds, the primary many-spored; the secondary few-spored	Subfamily III. **Thamnidieæ.**

Pilobolus crystallinus (Wigg.) Tode, a form with beautiful crystalline sporangia on yellowish, evanescent sporangiophores has been frequently noted as injuring or smudging chrysanthemum, rose and other leaves [121-122] by its profuse discharge of sporangia. It is not, however, a parasite.

Of the other genera the only ones of interest regarding plant disease are Rhizopus and Mucor. The others are saprophytes found on a great variety of substances, manure, fungi, and many other kinds of organic matter.

Rhizopus Ehrenberg (p. 104)

The sporangium wall is not cutinized, and falls away. The sporangia are all of one kind and with columellas. The sporangiophore is never dichotomous; zygotes are found in the mycelium. The suspensor is without outgrowths. Twelve or fifteen species, chiefly saprophytes.

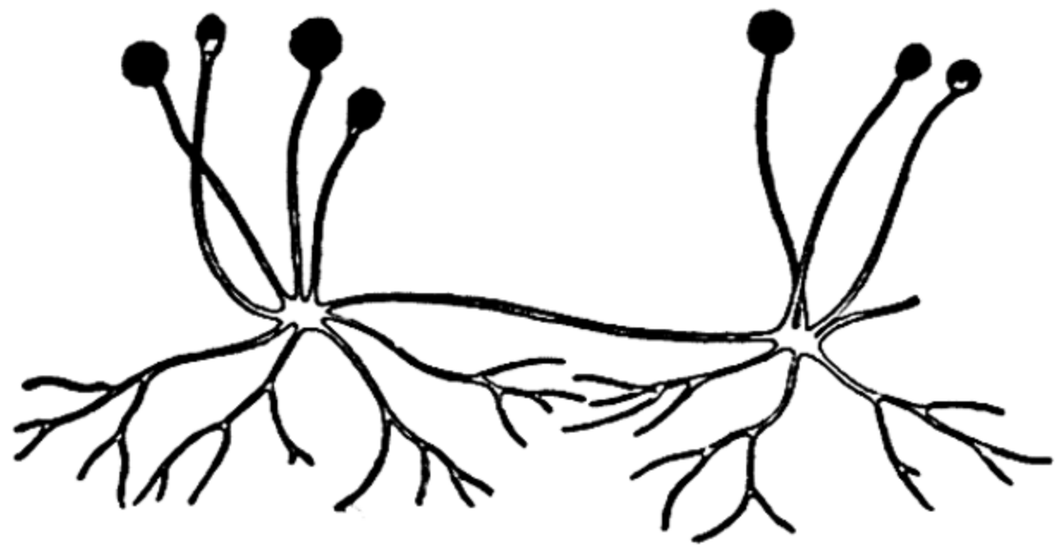


FIG. 72.—Rhizopus. Diagram showing mycelium and sporophores. After Coulter, Barnes and Cowles.

R. nigricans Ehr. Aërial mycelium at maturity chocolate-colored; rhizoids numerous; sporangiophores fasciculate, erect, aseptate; sporangia globose, blackish-olive, granular; columella hemispheric; spores gray to brown, subglobose or irregular, 11–14 μ; zygospore 150–200 μ, epispore with rounded warts, black. This is the cause of soft rot of stored vegetables, particularly of sweet potatoes,[123] also of Irish potatoes,[124] apples and pears; it causes death of squash blossoms [125] and is destructive to barley

during malting. It is distinctly a wound parasite and is unable to force entrance through a sound epidermis.

The richly branched mycelium which varies from very thin and hyaline to thick, coarse and slightly fuscous, is found throughout the rotten portion of the host. After a period of luxuriant vegetative growth hyphæ protrude to the air, first through existing ruptures in the epidermis, later by rifts forced by the fungus itself. Sporangiophores then form in dense bush-like growths, each sporangiophore bearing one terminal sporangium. The sporangia are at first white, later black and contain very numerous spores. Spore formation has been closely studied by Swingle.[126] Aërial stolon-like hyphæ reach out in various directions and at their points of contact with some solid develop holdfasts (Fig. 72) and a new cluster of sporangiophores.

Zygotes are produced by union of two mycelial tips as is shown in Fig. 70.

Orton [124] inoculated pure cultures of this fungus on sterile raw Irish potato and induced typical decay. He also noted that there was a difference in the rate of decay produced by strains of Rhizopus derived from different sources and that the most rapid decay of potatoes was caused by strains taken from rotting potatoes.

R. necans Mas.[127] causes decay of lily bulbs in Japan.

R. schizans Mas. is cited as the cause of split-stone in peach.[128]

Mucor Linnæus (p. 104)

Mycelium all of one kind, buried in the substratum or growing over its surface; sporangiophores scattered or not, simple or branched; sporangia globose; columella cylindric, pyriform or clavate; spores numerous, variable; zygospores globose, smooth or warty.

Some thirty species, chiefly saprophytes.

M. mucedo L. is destructive to beech nuts in winter.

M. pyriformis Fisch and **M. racemosus** Fes. cause decay of fruits.

Choanephoraceæ (p. 103)

Mycelium parasitic on living plants; sporangia of two kinds; macrosporangia globose, columella small, spiny, spores few, on

simple or branched, erect sporangiophores; microsporangia clavate, one-spored simulating conidia and borne in heads on the enlarged apices of umbellately branched sporangiophores; zygospores as in Mucoracæ.

A single genus, with three species.

Choanephora infundibulifera (Curry) Sacc. and **C. americana** A. Moll occur on blossoms in India and South America.

A third species, **C. cucurbitarum** (B. & Br.) Thaxter, is the cause of decay of cucurbits especially pumpkins, in the eastern and southern states.[129]

Entomophthorales (p. 66)

This order is predominately one parasitic on insects. Some fifty species are known, only four of which are plant parasites. Asexual reproduction is chiefly by conidia, apically borne and for the most part forcibly ejected from their stalks at maturity.

Key to Families of Entomophthorales

Endozoic parasites (Insecta, Arachnoidea).	1. **Entomophthoraceæ.**
Endophytic or saprophytic.	2. **Basidiobolaceæ,** p. 107.

Basidiobolaceæ

This family is characterized chiefly by its habitat. Septa are numerous in the vegetative mycelium.

Key to Genera of Basidiobolaceæ

Intracellular parasites, the mycelium greatly reduced.	1. **Completoria,** p. 108.
Saprophytes, or parasites on higher fungi, the mycelium well developed.	
Conidia produced directly from an unswollen conidiophore. Parasites on higher fungi.	2. **Conidiobolus.**
Conidia cut off from the apex of a swelling of the conidiophore. Saprophytic. . .	3. **Basidiobolus.**

With the exception of the one species given below these are not parasitic on higher plants.

Completoria complens Lohde is parasitic upon fern prothallia.[130]

Vegetative body compact, of oval or curved branches in a single host cell, extending to other cells by slender tubes. Resting spores 10 to 20, formed in the host cell. Propagation by non-motile conidia, 15–25 μ, in diameter.

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ASCOMYCETES (p. 64) [2, 7, 19, 25, 46, 52, 53, 62]

The distinguishing mark of this group is the **ascus.** This in its typical form is shown in Fig. 73, as a long, slender or club-shaped sac in which the spores are borne. The number of spores in the ascus is usually definite and is commonly of the series, 1, 2, 4, 8, 16, 32, 64, etc., the most common number being 8. The spores vary in size, color, shape, markings and septation. The asci in most genera are arranged in a definite group, a layer, constituting the **hymenium** which may be either concave, convex, or flat. Between the asci in the hymenium are often found slender hyphal threads of various form, the **paraphyses,** Fig. 73.



FIG. 73. — Portion of a hymenium showing asci and paraphyses. After Chamberlain.

The hymenium may be borne in or upon a firm substratum of woven threads, the **stroma,** or upon a very tenuous substratum, the **subiculum,** or without any definite subascal structure. The stromata vary widely in character, size, texture, color, surface, form, etc.

The mycelium is usually abundant, branched and septate, the septation readily distinguishing this group from the Phycomycetes. In many species the mycelium weaves together into a false parenchyma and constitutes relatively large spore-bearing structures. Fig. 74.

The ascigerous organ, **ascocarp,** or **ascoma,** if saucer-shaped and open is an **apothecium,** Fig. 92; if closed a **perithecium,** Fig. 144. In other cases, the ascigerous layer covers the exterior surface. Fig. 74.

On the boundary lines between the Ascomycetes and other groups are fungi which do not present the typical Ascomycete picture but which are regarded as probably belonging to the group, i. e., transition forms between this and other groups. Among such are

forms in which the asci are without either stroma or covering, (Protodiscales, p. 125); others in which the asci are not even in groups but are scattered irregularly throughout the ascocarp (Aspergillales, p. 164); and still others with the asci neither in regular groups nor covered (Protoascomycetes, p. 119). One further deviation from the typical form occurs in the Hemiascomycetes which possess a sporangium-like structure resembling that of the typical Zygomycete; but a mycelium like that of the typical Ascomycetes. This is by many regarded as the transition form bridging the gap between and indicating the kinship of these two groups; a view strongly supported by the existence of very similar sexual processes in the two groups.



FIG. 74.—The large ascocarp of the morel. After Freeman.

Besides the ascus the Ascomycetes possess many other kinds of

reproductive structures in the form of conidia. These may be borne singly or in rows on simple or branched conidiophores.

The conidiophores may be single or variously grouped in columns or layers. Figs. 352, 378, 382. In some instances they are very

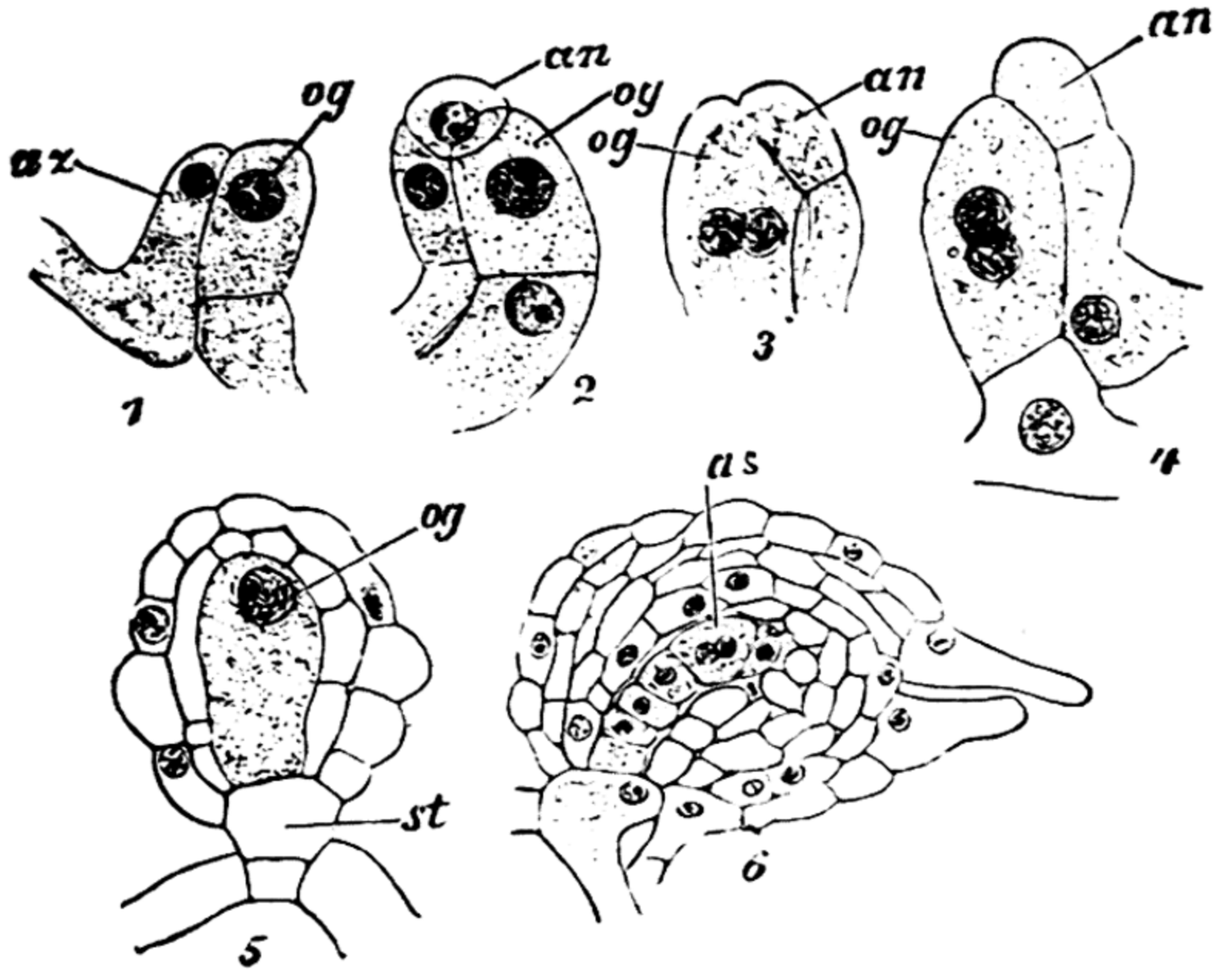


FIG. 75.—Sphærotheca castagnei. Fertilization and development of the perithecium. Og = oögonium, an = antheridium, st = stalk-cell. 6 as the ascogonium derived from the oögonium. After Harper.

short, innate; again they are long, loose or floccose. They may emerge through stomata singly or in tufts or they may form sporogenous cushions below the epidermis or again they may be borne inside of a hollow structure, the **pycnidium,** which covers them. **Chlamydospores** are also found.



FIG. 76.—Boudiera. Six sets of sexual organs. After Claussen.

One or several distinct types of sporification may belong to one species of Ascomycete. These different forms of spores may appear simultaneously on the same mycelium or they may follow in definite succession regulated by the changes in environment, or again one or more of the spore forms belonging to the life history of the fungus may be omitted for long intervals to appear only as the result of stimuli of which little is yet known.

The conidia and chlamydospores are asexual spores. Sexuality

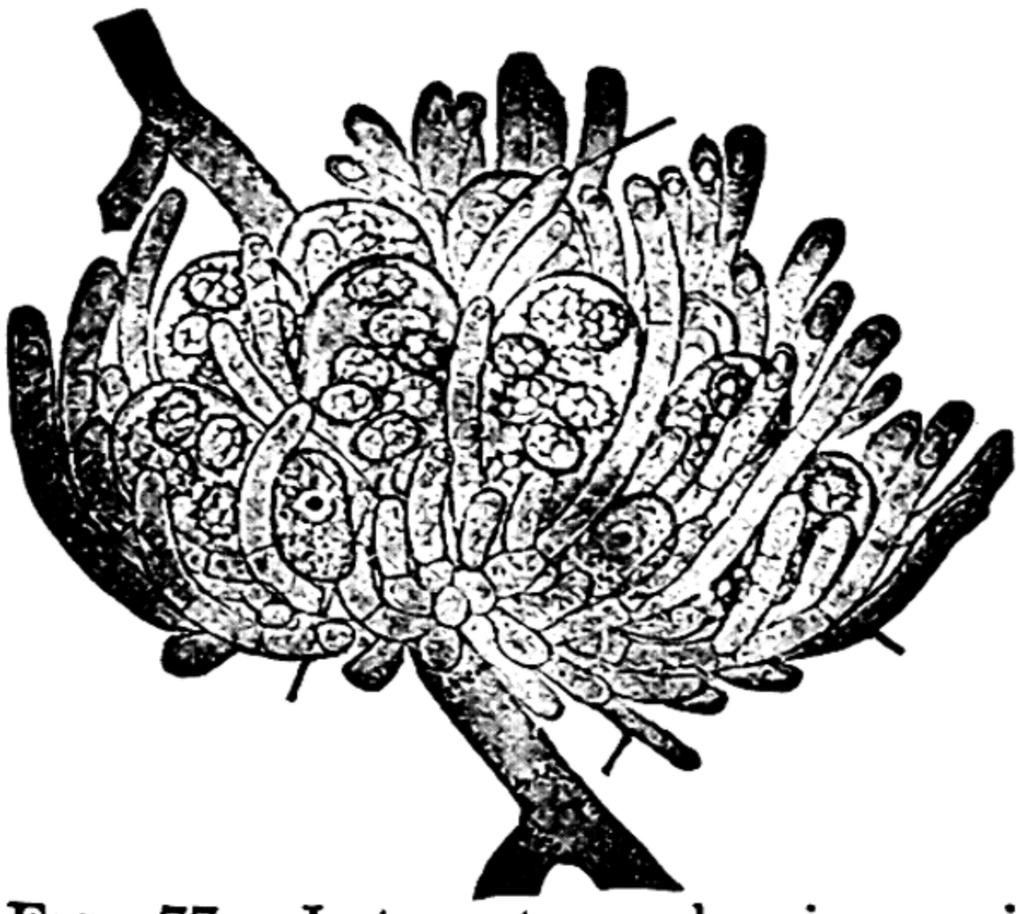


FIG. 77.—Later stage showing asci and ascophores. After Claussen.

in the great majority of Ascomycetes has not been investigated; but in some species fertilization is known to occur; in many species, at least in form similar to that shown by the Phycomycetes, it is absent, probably having been lost by degeneration or else very much modified.

In some of the Discomycetes there is one or more carpogonia and fertilization is through a trichogyne by spermatia; a mode often met among the lichens.

In Pyronema,[1] Fig. 78, the carpogonium is multi-nucleate and it is fertilized by a multi-nucleate antheridium through a trichogyne. Fu-

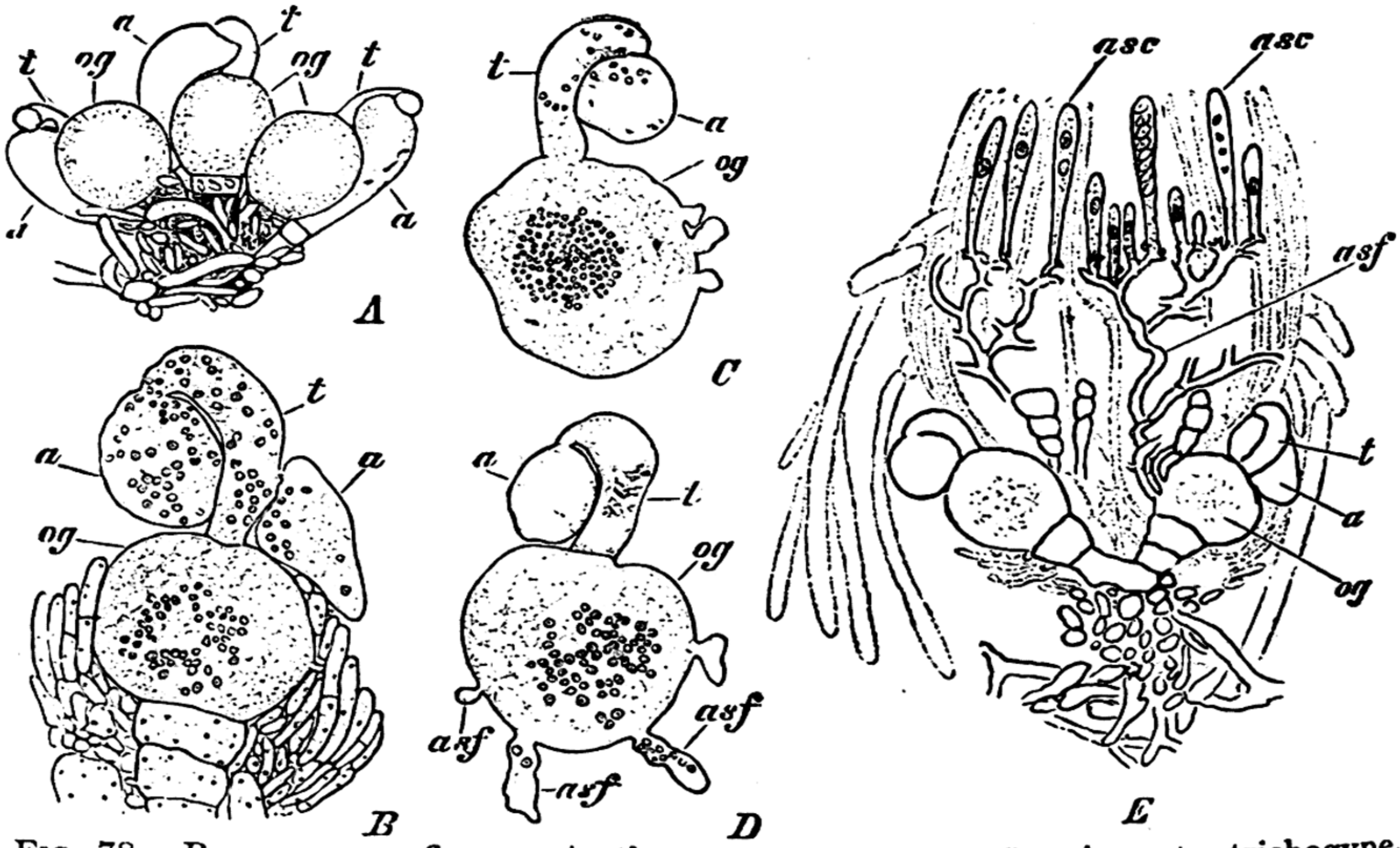


FIG. 78.—Pyronema confluens. A. the sex organs, og = oögonium, t = trichogyne. B. fertilization stage in section through young apothecium, asc = asci, asf = ascogenous filament. After Harper.

sion of nuclei is probably in pairs as in Albugo bliti of the Phycomycetes. In Boudiera [2] a very similar relation is found. Figs. 76, 77.

In some Perisporiales [3] an uninucleate oögonium is fertilized by an uninucleate antheridium. Fig. 75.

The **oögonium** after fertilization gives rise to a more or less complicated system of **ascogenous hyphæ,** very simple in the Erysiphaceæ, very complex in some Discomycetes, which produces the asci. The sterile parts of the ascocarp, the paraphyses and enveloping structures, arise from parts below the oögonium and antheridium.

The very young ascus usually receives two nuclei from the parent strand of the ascogenous hypha. These nuclei unite giving the

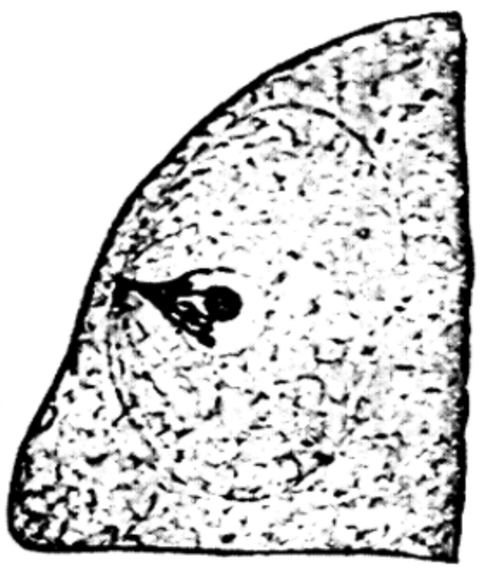


FIG. 79.—Tip of ascus of Erysiphe showing delimitation of ascospore from ascoplasm by astral rays. After Harper.

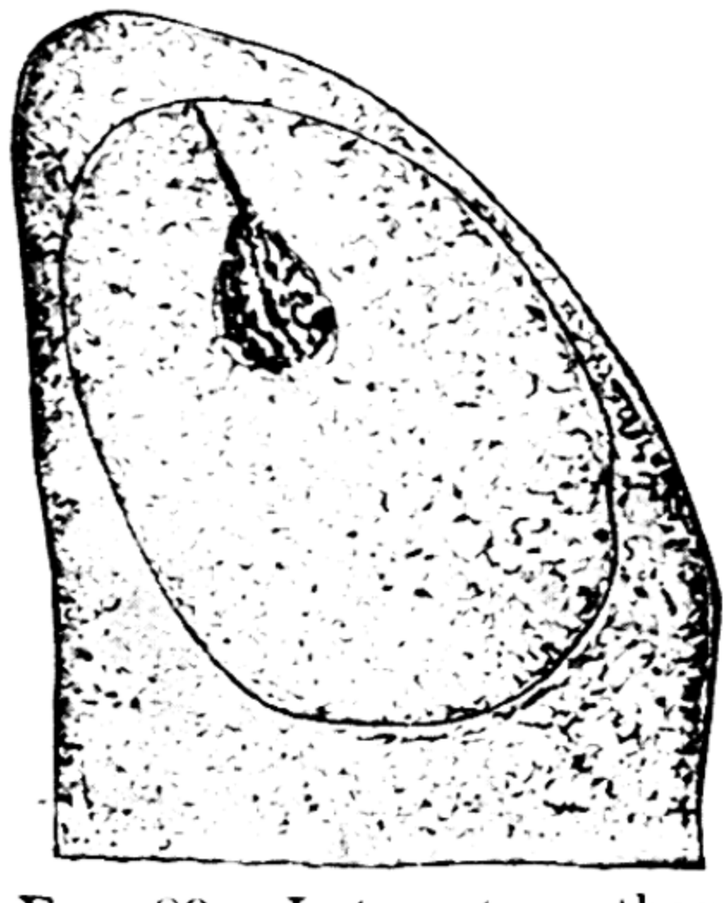


FIG. 80.—Later stage than fig. 79, showing well defined spore-wall. After Harper.

primary-ascus-nucleus. This by successive mitoses affords the single spore-nuclei. The spores are cut out from the protoplasm of the ascus in a most peculiar manner by reflexion of and union of astral rays which emanate from a centrosome-like organ at the beak of the prolonged nucleus. Figs. 79, 80.

The significance of two nuclear fusions in the life cycle of these fungi, one following the union of the antheridium with the oögonium, the other later, in the asci, is a puzzling phenomenon, the real significance of which is not clear.

KEY TO SUBCLASSES OF **Ascomycetes**

Asci with varying number of spores, usually numerous	1. **Hemiascomycetes,** p. 118.
Asci with definite number of spores	
Asci separate or scattered	2. **Protoascomycetes,** p. 119.
Asci approximate, usually forming a hymenium	3. **Euascomycetes,** p. 123.

Hemiascomycetes (p. 117)

There is a single order, the Protomycetales, which contains about twenty-five species. Mycelium filamentous, branched, septate; conidia present; asci sporangia-like, containing numerous spores, terminal, naked or covered with a hyphal felt; in some species known to originate from the fertilization of an oögonium.

Protomycetales

Key to Families of Protomycetales

Asci naked	
Asci long, tubular	1. **Ascoideaceæ.**
Asci elliptic or globular	2. **Protomycetaceæ,** p. 118.
Asci more or less covered by hyphæ	3. **Monascaceæ.**

Of these families the first is found in slime flux; the last is saprophytic.

Protomycetaceæ

Mycelium prominent; asci intercalary or terminal, large, development arrested before spores are formed; a process which is completed only after a period of rest.

Key to Genera of Protomycetaceæ

Parasitic, intercellular in living plants	1. **Protomyces,** p. 118.
Saprophytic, building hemispheric sporing masses	2. **Endogone.**

Protomyces Unger

Asci thick walled; after a long period of rest forming a large mass of elliptic spores which conjugate in pairs, then germinate immediately by a germ tube.

This genus is sometimes placed with the Phycomycetes.[22]

P. macrosporus Ung.

Asci globose to elliptic, 40–80 x 35–60 μ; membrane yellowish, up to 5 μ in thickness, contents colorless; spores elongate-ellipsoid, 2–3 x 1 μ.

It produces small galls, which are at first watery looking, then

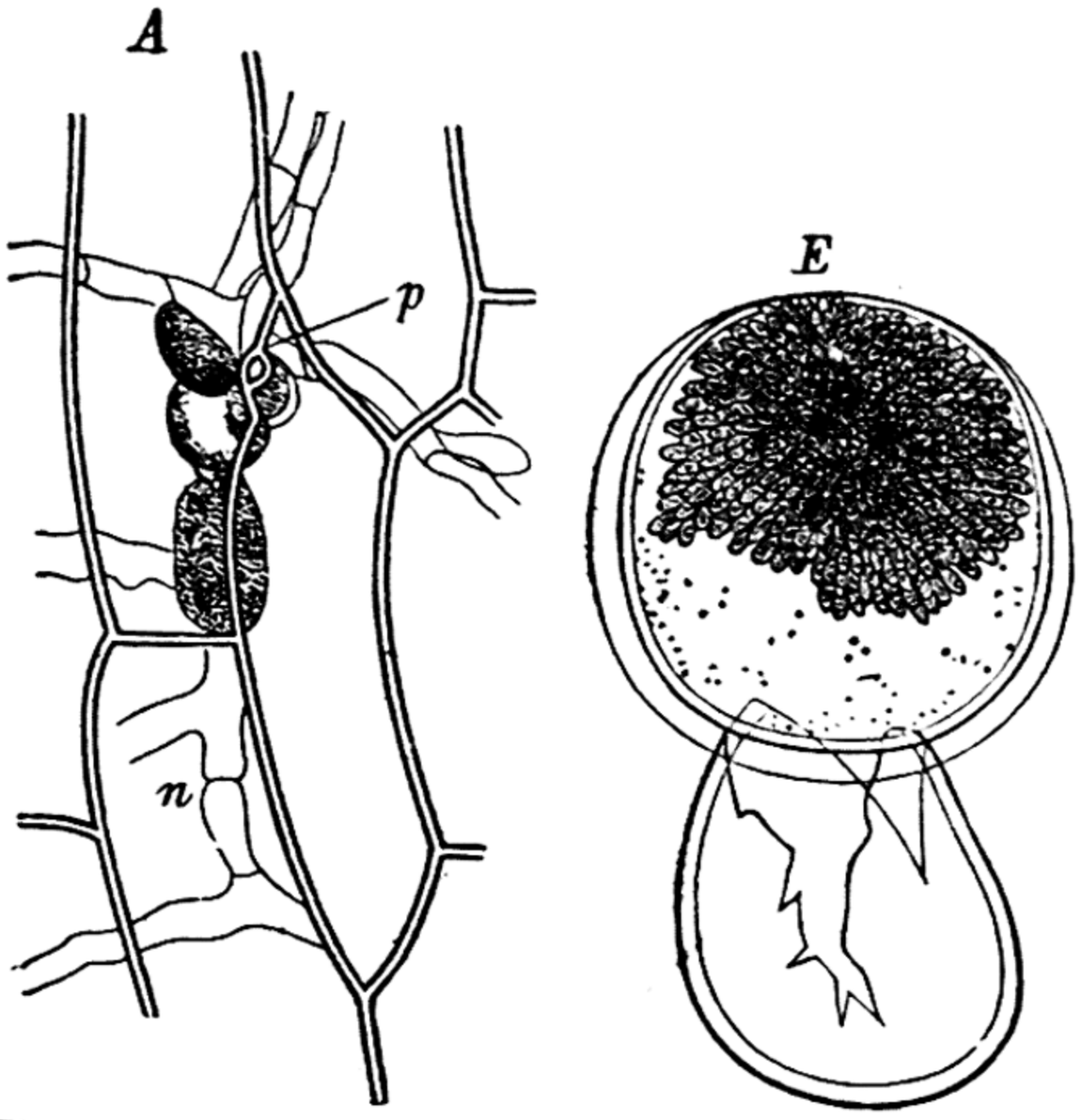


FIG. 81.—Protomyces. *A*, mycelium and young ascus; *E*, ascus with mature spores. After De Bary.

brown, upon the leaves and stems of various economic and non-economic Umbelliferæ.

P. pachydermus Thüm. affects carrots and dandelions.[22] **P. rhizobius** Trail, grows on Poa annua in Scotland. Several other species are found on wild plants.

Subclass **Protoascomycetes** (p. 117)

There is a single order, the Saccharomycetales, with about seventy species.

Mycelium often undeveloped; asci isolated or formed at different points on the mycelium, mainly 4-spored; spores unicellular; asexual reproduction by gemmation or by conidia.

Key to Families of **Saccharomycetales**

Vegetative cells single or loosely attached in irregular colonies, mycelium not usually developed, asci isolated, not differentiated from vegetative cells.	1. **Saccharomycetaceæ,** p. 120.
Vegetative cells forming a mycelium, asci terminal, or intercalary, differentiated from mycelium..	2. **Endomycetaceæ,** p. 122.

The first family, the yeasts, to which belong the majority of the species of the order, is of prime importance in fermentation. A few species are known to cause animal diseases; others are found associated with the slime fluxes.

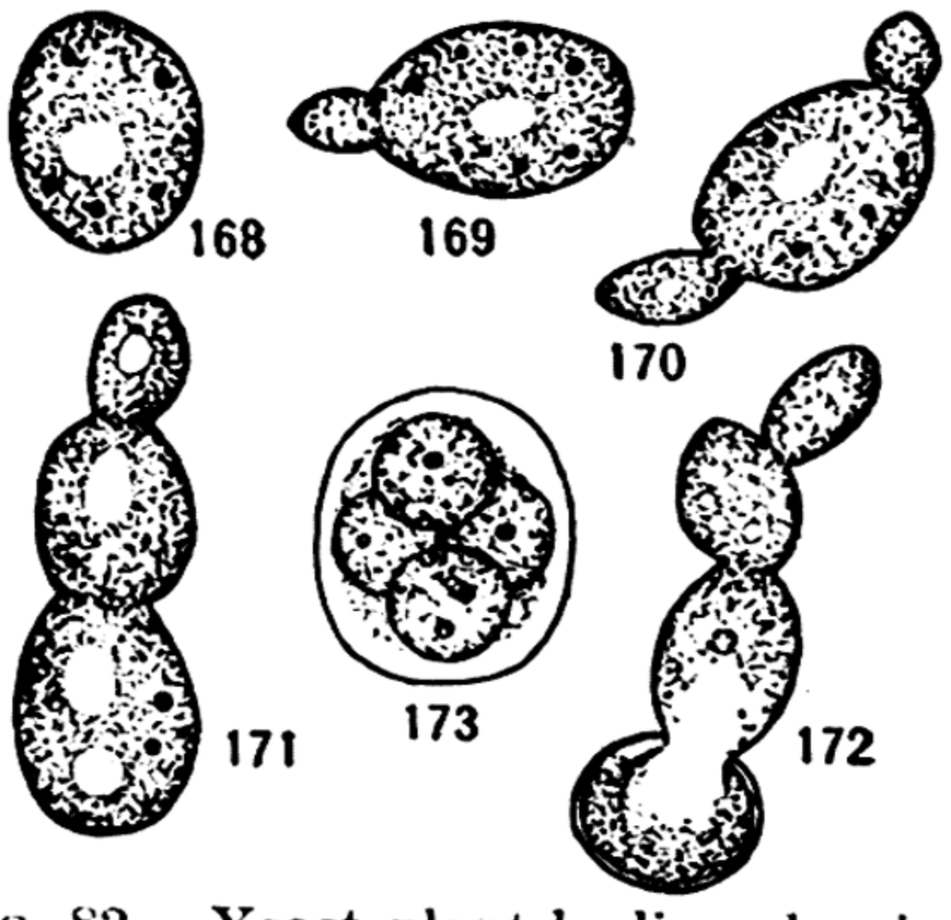


Fig. 82.—Yeast plant-bodies, showing budding and sporulation. After Coulter and Rees.

Saccharomycetaceæ

Vegetative cells separate or few together, never truly filamentous, propagating by buds; asci globose to elliptic, 1 to 8-spored; growing typically in sugary or starchy materials.

KEY TO GENERA OF **Saccharomycetaceæ**

Vegetative cells globose, ovoid, pyriform, etc.
Vegetative cells increasing by budding; asci typically 3 to 4 spored.
Spores globose or ovoid.
Spores upon germination forming typical yeast cells.
Ascus formation preceded by the conjugation of like gametes. . 1. **Zygosaccharomyces.**
Ascus formation not preceded by the conjugation of gametes.
Spore membrane single. . . . . 2. **Saccharomyces,** p. 121.
Spore membrane double. . . . . 3. **Saccharomycopsis.**
Spores upon germination forming a poorly developed promycelium. 4. **Saccharomycodes.**
Spores pileiform or limoniform, costate 5. **Willia.**
Spores hemispheric, angular or irregular in form, upon germination forming an extended promycelium. . . . . 6. **Pichia.**
Vegetative cells increasing by fission; asci 8-spored. . . . . 7. **Schizosaccharomyces.**
Vegetative cells elongate, cylindric; spores filiform,
Asci 1-spored. . . . . 8. **Monospora.**
Asci 8-spored. . . . . 9. **Nematospora,** p. 122.

Saccharomyces Meyen

Vegetative cells globose, ellipsoid, ovate, pyriform, etc., reproducing by budding and remaining attached in short, simple or branched pseudo-mycelial groups, at length separating; asci globose, ellipsoid, or cylindric, 1 to 4-spored (typically 3 to 4-spored), single or in chains; spores globose to ellipsoid, continuous.

Many species, chiefly saprophytes.

S. croci Roze is described as the cause of a crocus disease.[4]

From sorghum plants suffering from blight a yeast was isolated by Radais.[5] This when inoculated in pure culture into healthy plants produced the characteristic lesions and effects.

Nematospora Peglion (p. 121)

Colonies (in culture) disciform; cells elongate; asci cylindric, 8-spored; spores filiform, continuous, long-ciliate, hyaline.

Monotypic.

N. coryli Pegl.,[6] the cause of malformation of the hazel nut in Italy, is a peculiar fungus with what appears to be asci containing eight long slender flagellated spores.

Endomycetaceæ (p. 120)

Mycelium usually well developed, often producing a luxuriant growth, multiseptate; asci borne singly on branches, or intercalary, 4 to 8-spored; spores one-celled; conidia produced apically, unicellular.

KEY TO GENERA OF **Endomycetaceæ**

Mycelium poorly developed, parasitic on Mucorales.	1. **Podocapsa.**
Mycelium well developed	
Asci formed after conjugation of a pair of spirally entwined branches.	2. **Eremascus.**
Asci formed asexually, produced terminally, rarely intercalary.	
Asci 4-spored	3. **Endomyces,** p. 122.
Asci 8-spored	4. **Oleina.**

Endomyces Rees

Mycelium well developed, byssoid; asci borne singly on the ends of short lateral branches, globose to pyriform, 4-spored, spores continuous.

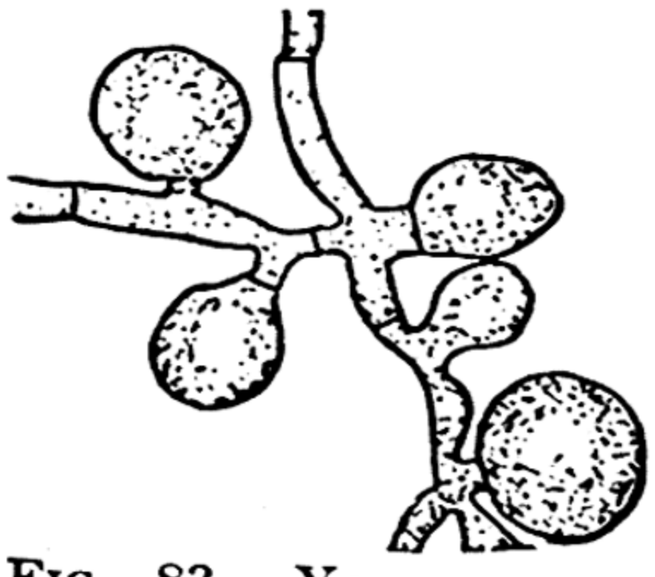


FIG. 83.—Young spore sacs of E. mali, spores later form in these. After Lewis.

The members of this genus are of questionable importance as parasites. Some are commonly found in sap exuding from tree wounds[27] where they, together with other fungi present, set up a fermentation the products of which prevent the wound from healing and result in injury. One species has been reported in America as an active parasite on apples.

E. mali Lewis [7]

Mycelium well developed, multiseptate; conidia formed on short conidiophores or on the ends of short germ tubes, averaging 3 x 8 μ; no yeast-like budding; asci usually on short lateral branches, 11–14 μ in diameter; ascospores sphæroidal, slightly elongate, 4.5 x 5.5 μ with thickened places on the walls, brown when mature. Figs. 83, 84.



FIG. 84.—E. mali. Typical manner of bearing conidia on agar. After Lewis.

Lewis isolated the fungus from decayed spots on apples by plate cultures. Inoculations proved that it is capable of causing a slow decay without the aid of other fungi. An extensive cultural study as well as a considerable cytological study was made.

E. decipiens (Tul.) Rees is parasitic on Armillaria; **E. parasitica** Fayod on Tricholoma.[19, 27]

Euascomycetes (p. 117)

This is an extraordinarily large group comprising some 16,000 species, with great variety of size, color and shape of plant body. Most of them are saprophytes, still many are parasites either in their ascigerous or their conidial stages of development.

The twelve orders may be recognized by the following key.

KEY TO ORDERS OF Euascomycetes

Asci approximate in an indefinite hymenium, no ascoma. ..... 1. **Protodiscales,** p. 125.

Asci grouped in a definite ascoma

Asci collected in a flattened, concave or closed ascoma, often bordered by a distinct layer

Ascoma at maturity open and more or less cup-like. Discomycetes

Ascoma open from the first, clavate or convex, pitted, or gyrose..... 2. **Helvellales,** p. 130.

Ascoma at first closed, opening early, without special covering, more or less fleshy..... 3. **Pezizales,** p. 133.

Ascoma opening tardily, enclosed by a tough covering which becomes torn open at the maturity of the spores

Ascoma roundish, opening by stellate or radiating fissures. . . . . 4. **Phacidiales,** p. 154.

Ascoma elongate, opening by a longitudinal fissure. . . . . 5. **Hysteriales,** p. 159.

Ascoma at maturity closed and tuber-like, subterranean,. . . . . 6. **Tuberales.**

Asci collected in a cylindric or globose perithecium

Perithecia sessile, solitary and free, or united and embedded in a stroma

Asci arranged at different levels in the perithecium. . . . . 7. **Aspergillales,** p. 164.

Asci arising from a common level

Mycelium superficial, perithecia scattered, globose and without apparent ostiole, or flattened and ostiolate. . . . . 8. **Perisporiales,** p. 170.

Mycelium nearly superficial, perithecia ostiolate

Perithecia and stroma (if present) fleshy or membranous, bright colored. . . . . 9. **Hypocreales,** p. 195.

Perithecia and stroma (if present) hardened, rarely membranous, dark colored

Wall of perithecia scarcely distinguishable from the stroma. . . . . 10. **Dothidiales,** p. 215.

Perithecia with distinct wall, free or embedded in the stroma. . . . . 11. **Sphæriales,** p. 221.

Perithecium borne on a short pedicel; microscopic fungi parasitic on insects. . . . . 12. **Laboulbeniales.**

Of these all contain plant parasites with two exceptions; the Tuberales, which bear underground tuber-like ascocarps, some of

these prized as table delicacies, and the Laboulbeniales, an order rich in species which are all parasitic upon insects.

Protodiscales (p. 123)

The 4–8 to many-spored asci form a flat palisade-like hymenium which arises directly from the mycelium; paraphyses none; spores, one-celled, elliptical or round.

Key to Families of **Protodiscales**

Parasitic	1. **Exoascaceæ,** p. 125.
Saprophytic	2. **Ascocorticiaceæ.**

Of these families the second contains only one genus and two species found in bark. The first family is aggressively parasitic.

Exoascaceæ [8-10, 292, 327]

This is the most simple of the parasitic Ascomycetes, definitely recognizable as such, and is comparable with the Exobasidiales among the Basidiomycetes. All the species are parasitic and many of them very injurious. The mycelium, which can be distinguished from that of other fungi by its cells of very irregular size and shape, wanders between the host cells (intracellular in one species), or is sometimes limited to the region just below the cuticle. The asci develop in a palisade form on a mycelial network under the epidermis, or the cuticle, or on the ends of hyphæ arising from below the epidermal cells. They are exposed by the rupture of the cuticle or epidermis and contain four to eight hyaline, oval, one-celled spores. These by budding, while still in the ascus, may produce numerous secondary spores, conidia, which give the impression of a many-spored ascus. The ascospores also bud freely in nutritive solutions. The primary-ascus-nucleus arises from

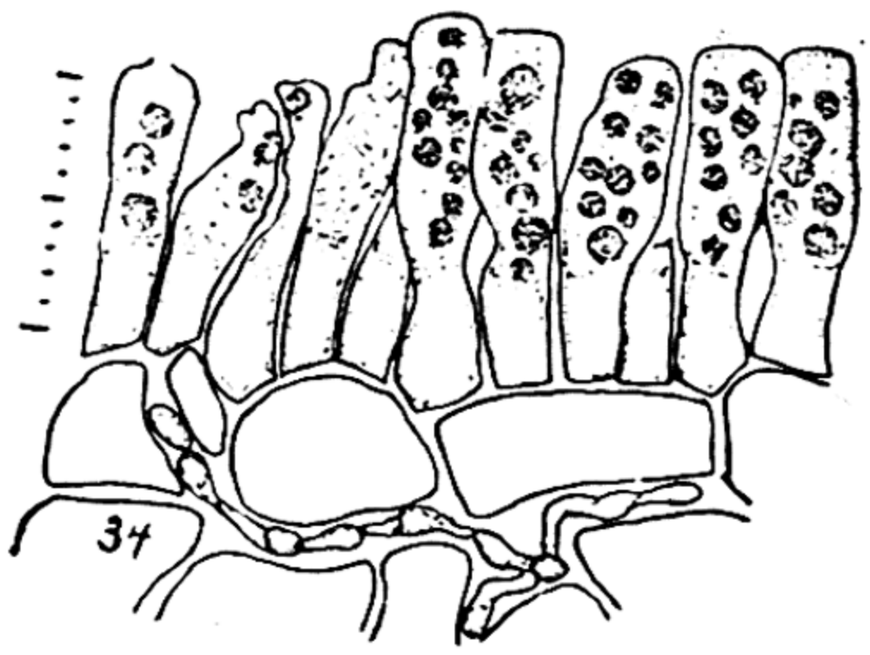


Fig. 85.—Exoascus showing mycelium and asci. After Atkinson.

fusion of two nuclei as is general among the Ascomycetes. The spore-nuclei arise by repeated mitoses of the primary nucleus.

Affected leaves, fruit and twigs become swollen and much distorted; wrinkled, curled, arched, puckered. In woody twigs the mycelium often induces unnatural, profuse, tufted branching resulting in "witches brooms" though such structures often arise from irritation due to other causes.

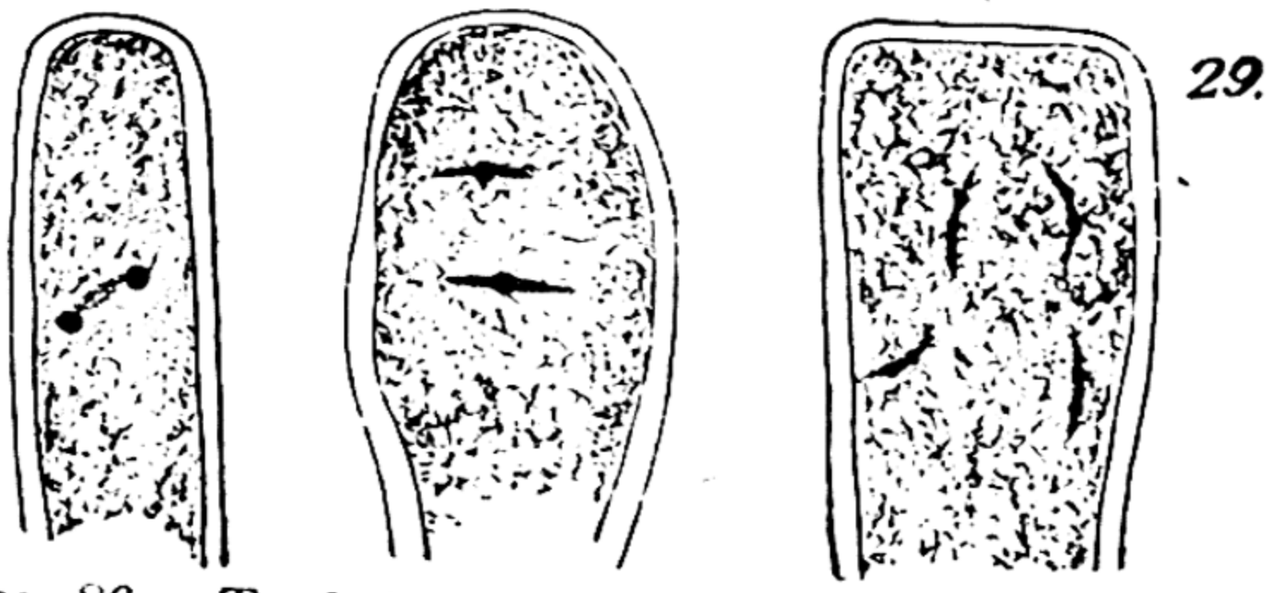


FIG. 86.—Taphrina showing mitoses in the young ascus leading to the development of spore-nuclei. After Ikeno.

Many attempts have been made to arrange the species in natural genera; some based on the number of ascospores,[6, 354] others largely on the biologic grounds of annual or perennial mycelium.[9] Giesenhagen [10] whose classification is followed here, recognizes two genera, Exoascus being merged into Taphrina.

KEY TO GENERA OF **Exoascaceæ**

Asci cylindric, clavate or abbreviate-cylindric, produced above the epidermis of the host. . . . . 1. **Taphrina,** p. 126.

Asci saccate, in epidermis . . . . . 2. **Magnusiella.**

Taphrina Fries

Mycelium annual or perennial; asci 4 to 8-spored, or by germination of the ascospores, multispored, borne on the surface of blisters and other hypertrophied areas, cylindric to clavate, or a modification thereof. Of this genus Giesenhagen [10] recognizes four series of species which are arranged in three subgenera.

Subgenus 1. **Taphrinopsis,**—one series (Filicina)

The asci are slender clavate, narrowed at each end, rounded above, broadest in the upper fourth. Parasitic on ferns. None of the five species is of economic importance.

Subgenus. 2. **Eutaphrina,**—one series (Betula)

Asci broadly cylindric, rarely contracted at the base or from the middle down, truncate above and sometimes in-sunken. On Amentaceæ, chiefly Betula, Alnus, Ostrya, Carpinus, Quercus, Populus. Of the twenty-four species of this series but few are of importance.

T. cœrulescens (D. & M.) Tul.[11] Annual, producing blisters on the leaves of oak, the sporing surface bluish; asci elongate, broadly cylindric, 55–78 x 18–24 μ; spores breaking up into conidia.

On various species of Quercus in Europe and America.

T. ulmi (Fcl.) Joh., on the elm; **T. aurea** (Pers.) Fries on the leaves of Populus and **T. johonsonii** Sad. on the fertile aments of the aspen are among the more important remaining species of the series.

Subgenus 3. **Exoascus,**—two series

Asci clavate, normally cylindric or more or less abbreviated.

(1) Prunus series on Rosaceæ. Asci slender, clavate, narrowed below, broadest in their upper fourth, varying through all intermediate forms to narrowly cylindric.

(2) Æsculus series, on Sapindacæ, Anacardiaceæ, etc.—Asci broadly cylindric, short, rounded or truncate.

The more important economic species of the genus belong to the Prunus series.

T. deformans (Fcl.) Tul.[8, 12, 13]

The irregular vegetative mycelium devoid of haustoria grows in the leaf parenchyma and petiole and in the cortex of branches. A distributive mycelium lies close beneath the epidermal cells of twigs and in the pith and extends some distance through the twig. Fig. 87. Branches arise from the vegetative mycelium, penetrate between the epidermal cells to the cuticle and then branch freely to form a network of short distended cells beneath the cuticle. This is the hymenium, a layer of ascogenous cells. These cells elongate perpendicularly to the host's surface, Fig. 85, rupture the cuticle, and form a plush-like layer. The protoplasmic con-

tents crowds toward the tips of these cells and a basal septum cuts off the ascus proper from the stalk cell, Fig. 88. The spores then form within the ascus. The ascospores may bud either before or after extrusion from the ascus, producing conidia, which may themselves bud indefinitely, producing secondary, tertiary, etc., crops. In this condition the conidia strongly resemble yeast cells. On the host plant ascospores germinate by germ tubes, which are capable of infecting proper hosts. No success has rewarded attempts to secure germ tubes from conidia. Leaf infection is chiefly external; rarely internal from mycelium perennating in the twigs. It occurs when the leaf is very young. Infected leaves are thickened and broadened and the tissues are stiff and coriaceous. The palisade cells increase in size and number and lose their chlorophyll. Blistering and reddening of the leaves follows.

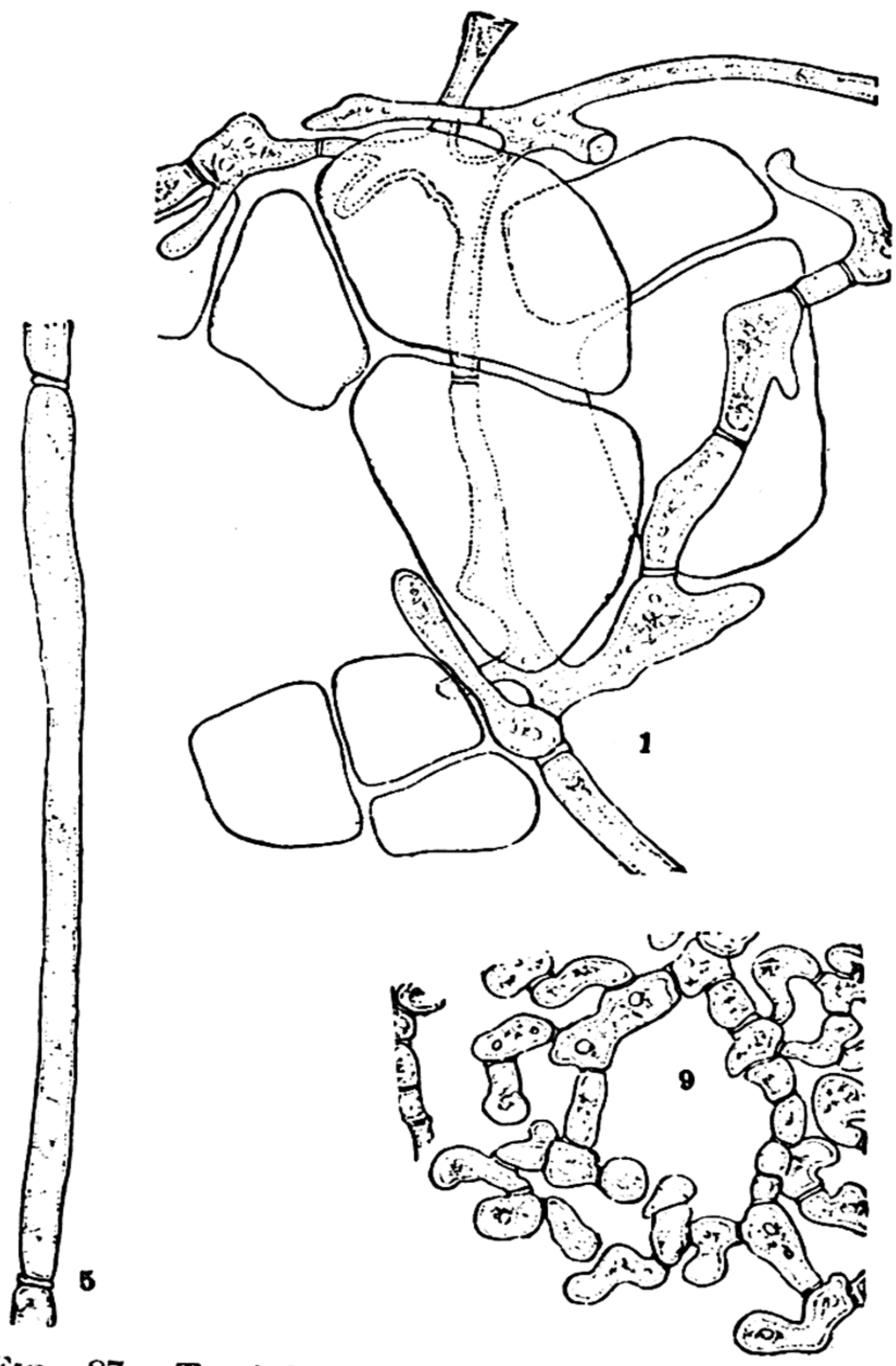


FIG. 87.—T. deformans. 5, distributive hypha; 1, vegetative hyphæ; 9, sporiferous hyphæ. After Pierce.

Asci clavate, 25–40 x 8–11 μ; spores 8, subglobose or oval, 3–4 μ. On the peach in Europe, North America, China, Japan, Algeria and South Africa.

T. pruni (Fcl.) Tul.[8, 14] is found in Europe and North America

on plum and wild cherry, causing "plum pockets." The ovary is the seat of attack. The mycelium after bud infection pervades the mesocarp which hypertrophies and alone produces a much enlarged fruit, usually with entire sacrifice of the other fruit parts. Asci are formed over the diseased surface much as in the last species. The mycelium is perennial in the bast and grows out into the new shoots and buds each spring. Infection also reaches other shoots and trees by means of the spores.

Ascus elongate-cylindric, 30–60 x 8–15 μ; spores 8, globose 4–5 μ. Perennial.

T. cerasi (Fcl.) Sad.[8, 15] produces the witches broom effect upon cultivated and wild cherries. It is common in Europe, rare in America. Perennial; asci clavate 30–50 x 7–10 μ; spores 8, forming conidia in the ascus, oval, 6–9 x 5–7 μ.

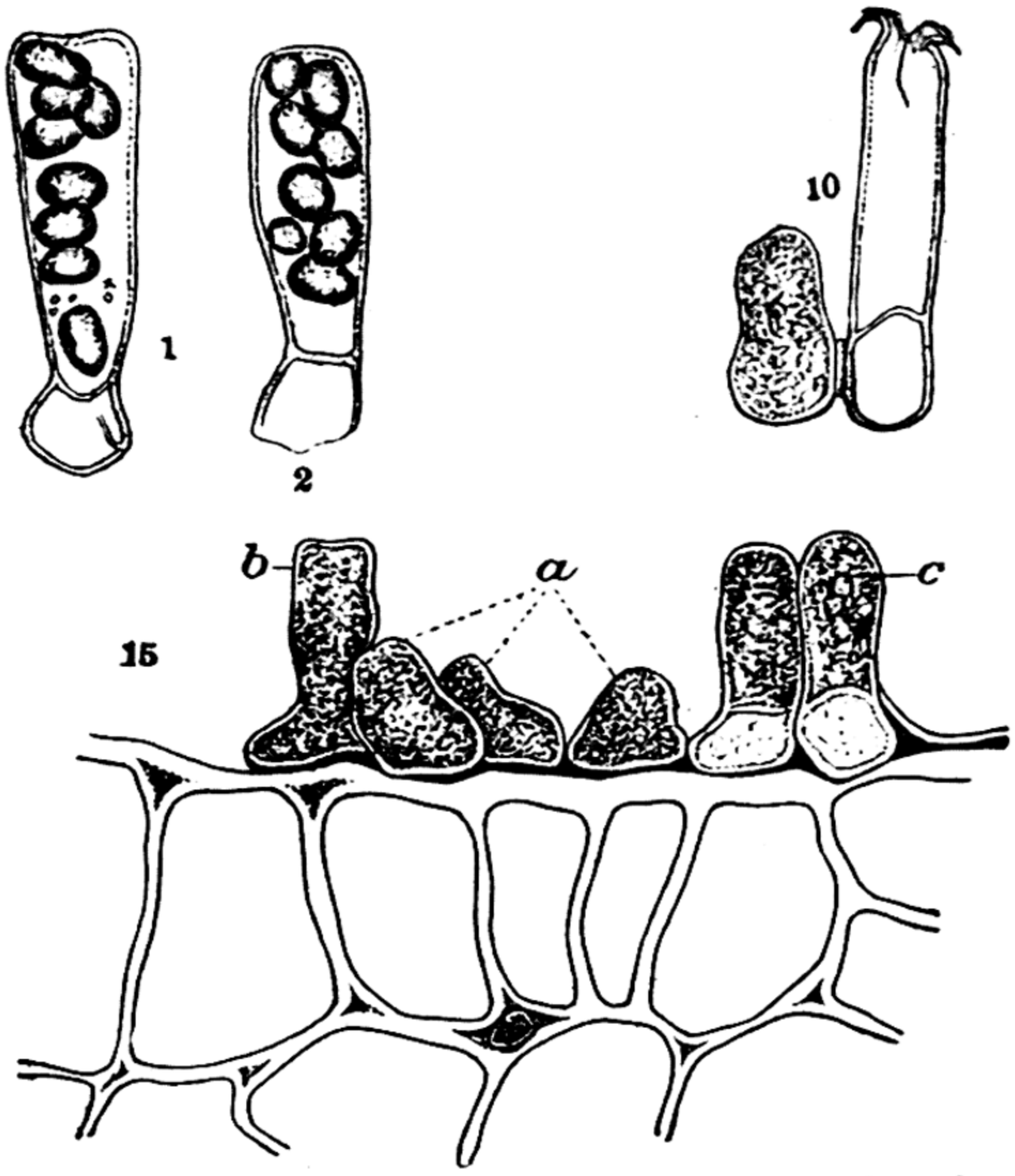


FIG. 88.—T. deformans. Young and old asci. After Pierce.

On Prunus avium, P. cerasus, etc. in North America and Europe.

T. mirabilis (Atk.) Gies.[8, 16] grows on leaf buds and twigs of Prunus angustifolia, P. hortulana, P. americana in North America.

Perennial; sporing on the fruits and tips of branches of the host; asci subcylindric, blunt above, 25–45 x 8–10 μ; spores 8, ovate.

T. longipes (Atk.) Gies. is on Prunus americana in North America, causing plum pockets.[8]

Perennial; sporing on young fruits; asci cylindric, truncate or not, 30–40 x 7–10 μ; spores 8, globose or ovate, 3–4 μ.

T. rhizipes (Atk.) Gies. Known only in North America, causing pockets on Japanese plums;[8] probably of wider distribution.

Perennial; asci cylindric, or club-shaped, 30–40 x 8–10 μ, appearing to have basal rhizoids; spores 8, globose.

T. communis (Sad.) Gies.[8] Perennial in branches; sporing on immature fruits; asci clavate, 24–45 x 6–10 μ; spores 8, elliptic, 5 x 3–4 μ, often producing conidia.

On Prunus americana, P. maritima, P. nigra, and P. pumila, in North America.

T. institiæ (Sad.) Joh. Forming witches brooms on Prunus institia, P. domestica, and P. pennsylvanica in Europe and America.[8]

Perennial; sporing on the under side of the leaf; asci clavate to cylindric, 25–30 x 8–10 μ; spores 8, not rarely producing conidia, globose, 3.5 μ.

T. decipiens (Atk.) Gies. On Prunus americana in North America.[8]

Perennial; sporing on under surfaces of leaves; asci irregularly clavate, often almost cylindric, 20–40 x 10 μ; spores breaking up into conidia.

T. bullata (Fcl.) Tul. On pear and Japanese quince.

Annual; asci clavate, 36–40 x 8–9 μ; spores 8, often forming conidia, globose, about 5 μ.

T. farlowii (Sad.) Gies.[8] is found on Prunus serotina in America; **T. minor** Sad. on leaves of Prunus chamæcerasus and P. cerasus, in Germany and England. It has recently caused considerable damage in South England.

T. bassei Fab. causes witches broom of cacao in Kamerun.

T. rostrupiana (Sad.) Gies. is on Prunus spinosa;

T. cratægi (Fcl.) Sad. on Cratægus oxycantha.

T. maculans Butler is reported on Tumeric and Zinzibar by Butler.[288] **T. theobromæ** Ritzema Bos. is reported as injurious to the cacao tree.

Many **other species** of Taphrina of minor importance occur upon alder, poplar (Populus), Carpinus, birch, elm, maple, hawthorn, oak and numerous other hosts.

Helvellales (p. 123)

Ascoma fleshy, separable into a definite hymenium of asci and paraphyses and a stroma which is usually large and stalk-like;

fertile portion more or less cap-like; hymenium free from the first or covered with a thin, evanescent veil; [17] asci cylindric, opening by an apical pore; spores ellipsoid, colorless or light yellow, smooth, or in one genus echinulate.

Key to Families of Helvellales

Ascocarp stalked
- Fertile portion clavate or capitate; asci opening by an irregular slit..... 1. **Geoglossaceæ,** p. 131.
- Fertile portion pileate; asci opening by a lid. 2. **Helvellaceæ.**

Ascocarp sessile..... 3. **Rhizinaceæ,** p. 132.

The majority of the species of this order are saprophytes, the only parasites being of the first and third families. Of the second family many of the species are edible and some are very large.

Geoglossaceæ

Key to Tribes and Genera of Geoglossaceæ

Ascoma clavate or spatulate, ascigerous portion usually more or less compressed, rarely subglobose.... Tribe I. **Geoglosseæ.**

Ascoma clavate, fertile portion at most only slightly decurrent
- Spores small, elliptic, cylindric or fusiform, continuous; plants bright colored ..... 1. **Mitrula,** p. 132.
- Spores long, elliptic to cylindric, 3 to many-septate at maturity
  - Hymenium bright colored ..... 2. **Microglossum.**
  - Hymenium black or blackish
    - Spores hyaline ..... 3. **Corynetes.**
    - Spores brown..... 4. **Geoglossum.**

Ascoma spatulate or fan-shaped, ascigerous portion decurrent on the stipe
- Ascigerous only on one side of the stem. ..... 5. **Hemiglossum.**
- Ascigerous on both sides the stem
  - Spores globose ..... 6. **Neolecta.**
  - Spores elongate ..... 7. **Spathularia.**

Ascoma stalked, capitate or pileate, in one genus sessile..... II. **Cudonieæ.**

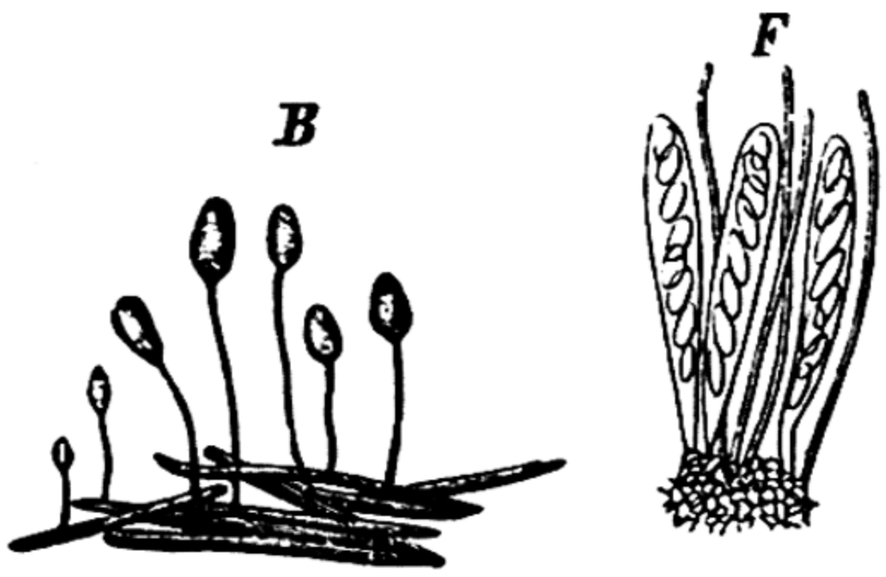


FIG. 89. — Mitrula. *B*, habit sketch; *F*, asci. After Schröter.

Mitrula sclerotiorum Rost.[18] which causes a disease of alfalfa in Denmark is the only pathogen of the family. The infected plants die and later the roots and stems become filled with black sclerotia which lie dormant about a year. Upon resuming growth they become covered by light red elevations, which bear small light red ascocarps.

Rhizinaceæ (p. 131)

KEY TO GENERA OF Rhizinaceæ

Spores elliptic or spindle-shaped	
Without rhizoid-like structures.	1. **Psilopezia.**
With rhizoid-like structures.	2. **Rhizina,** p. 132.
Spores globose	3. **Sphærosoma.**

Only one genus, Rhizina, causes disease.

Rhizina Fries with some eight species is recognized by its crust-formed, sessile, flat ascophore with root-like outgrowths from the lower side. Fig. 90. Asci cylindrical, 8-spored, opening by a lid; spores one-celled, hyaline; paraphyses many. It is often purely saprophytic, growing in burned-over spots in forests.

R. inflata (Schäff) Quel.[19, 55] is counted as the cause of serious root diseases of forest trees, especially conifers, in Europe. The fungus also occurs in Asia and America.

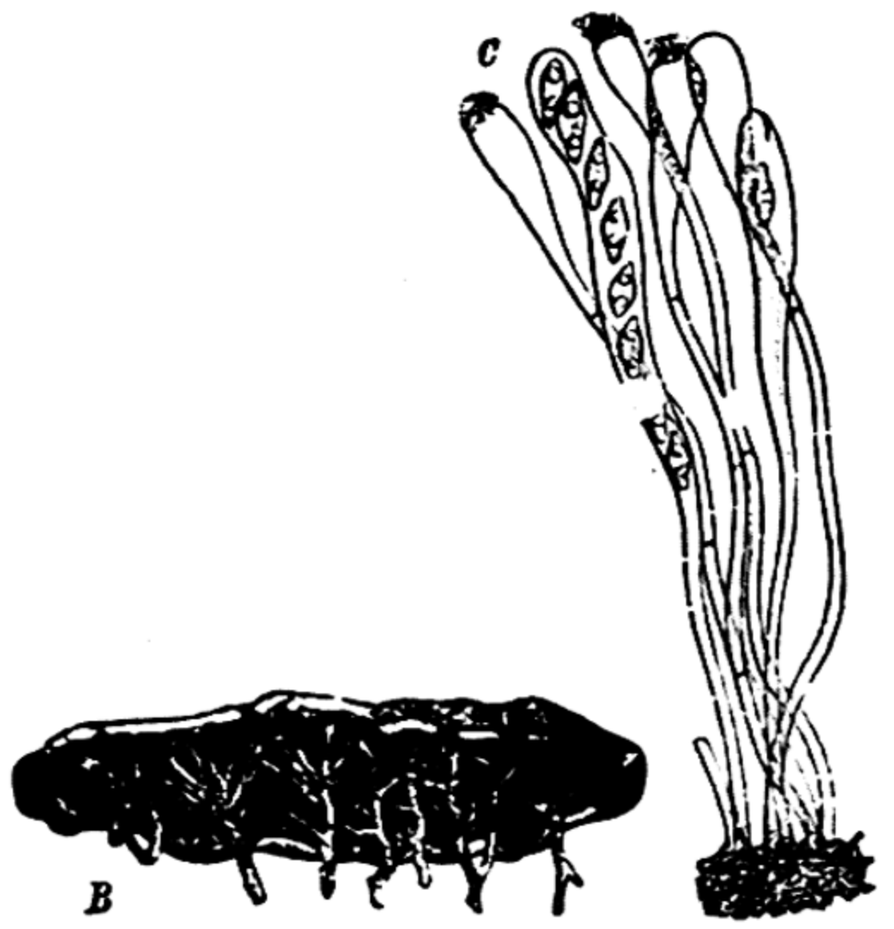


FIG. 90. — Rhizina inflata. *B*, ascocarp from below; *C*, asci and paraphyses. After Schröter and Tulasne.

R. undulata causes death of fir seedlings.[289]

Pezizales (p. 123)

In this order unlike the last, the hymenium is at first enclosed but soon becomes exposed. The apothecia at maturity are typically disc or saucer-shaped (Fig. 101) or sometimes deeper, as cup, beaker or pitcher-shaped. They vary from a size barely visible up to 8–10 cm. in diameter. Some are stalked, more often they are sessile. In consistency they vary from fleshy or even gelatinous to horny. Paraphyses are present and may unite over the asci to form a covering, the **epithecium.** The apothecium may be differentiated into two layers; the upper bearing the asci is the **hypothecium,** the lower the **peridium.** In some cases sclerotia are formed. Many species possess conidiospores as well as ascospores, borne either on hyphæ or in pycnidia. The great majority are saprophytes, a few are parasitic. There are some three thousand species.

Key to Families of **Pezizales**

No lichenoid thallus and no algal cells
  Ascocarps free, solitary or cespitose
    Ascocarps fleshy or waxy, rarely gelatinous; ends of paraphyses free
      Peridium and hypothecium without distinct lines of junction
        Ascoma open from the beginning, convex; peridium wanting or poorly developed. . . . . 1. **Pyronemaceæ.**
        Ascoma concave at first; a fleshy peridium present.
          Asci forming a uniform stratum, at maturity not projecting. 2. **Pezizaceæ.**
          Asci projecting from the ascoma at maturity. . . . . 3. **Ascobolaceæ.**
      Peridium forming a more or less differentiated membrane.
        Peridium of elongate, parallel pseudo-parenchymatous, hyaline, thin-walled cells . . . . . 4. **Helotiaceæ,** p. 134.

Peridium firm, of roundish or angular, pesudo-parenchymatous, mostly dark, thick-walled cells	5. **Mollisiaceæ**, p. 146.
Ascocarps leathery, horny or cartilaginous; ends of the paraphyses united into an epithecium	
Peridium wanting or poorly developed.	6. **Celidiaceæ.**
Peridium well developed, mostly leathery or horny	
Ascocarps free from the beginning, dish or plate-shaped, never enclosed by a membrane.	7. **Patellariaceæ.**
Ascocarps at first embedded in a matrix, then erumpent, urceolate or cup-shaped, at first enclosed in a membrane which disappears later.	8. **Cenangiaceæ**, p. 150.
Ascocarps borne on a highly developed stringy or globoid stroma	
Ascocarps at the ends of the branches of a cord-like stroma.	9. **Cordieritidaceæ.**
Ascocarps embedded in the upper portion of a globoid stroma.	10. **Cyttariaceæ.**
Lichenoid thallus more or less prominent, algal cells typically present, asci disappearing early, disk with a mazædium. .	11. **Caliciaceæ**, p. 153.

The Pyronemaceæ, Peziaceæ, and Ascobolaceæ are pure saprophytes on organic matter in the ground or on rotting wood. The Patellariaceæ are largely, and the Celidiaceæ are nearly all, parasitic on lichens. The Cordieritidaceæ of four species, possessing a stony stroma, are unimportant. The Cyttariaceæ, of one genus, and some six species, are limited to the southern hemisphere where they grow on branches of the beech.

Helotiaceæ (p. 133)

In members of this family there is a distinctly differentiated peridium. The apothecia are usually fleshy or waxy, superficial, first closed, later opening; the paraphyses form no epithecium. Asci 8-spored. Spores round to thread-shaped, one to 8-celled,

hyaline. Some of the genera are among the most serious of plant pathogens. About one thousand species.

KEY TO GENERA OF **Helotiaceæ**

Ascocarps fleshy, fleshy-waxy, thick or membranous
  Ascocarps fleshy-waxy, brittle when fresh, leathery when dry. ..... I. **Sarcoscypheæ.**
    Ascocarps felty hairy externally. ..... 1. **Sarcoscypha.**
    Ascocarps covered with bristle-like hairs externally..... 2. **Pilocratera.**
    Ascocarps naked
      Ascocarps springing from a sclerotium..... 3. **Sclerotinia,** p. 136.
      Ascocarps not springing from a sclerotium
        Spores 1-celled
          Substratum green..... 4. **Chlorosplenium,** p. 144.
          Substratum uncolored..... 5. **Ciboria.**
        Spores at length 2 to 4-celled.... 6. **Rutstrœmia.**
Ascocarps waxy, thick, tough or membranous
  Ascocarps externally hairy..... II. **Trichopezizeæ.**
    Ascocarps resting on an extended arachnoid mycelium
      Spores 1-celled..... 7. **Eriopeziza.**
      Spores becoming several-celled... 8. **Arachnopeziza.**
    Ascocarps without arachnoid mycelium
      Spores globose..... 9. **Lachnellula.**
      Spores ellipsoid or elongate
        Disk surrounded by black hairs. 10. **Desmazierella.**
        Disk smooth
          Paraphyses obtuse at the apex
            Walls of ascoma delicate; spores mostly 1-celled, rarely 2-celled at maturity..... 11. **Dasyscypha,** p. 144.
            Walls of ascoma thick; spores 2-celled at maturity..... 12. **Lachnella,** p. 145.

Paraphyses lancet-shaped at apex
Spores 1-celled. . . . . 13. **Lachnum.**
Spores at length several-celled. . . . . 14. **Erinella.**
Ascocarps naked. . . . . III. **Helotieæ.**
Spores globose. . . . . 15. **Pitya.**
Spores ellipsoid or fusiform
Spores 1-celled
Border of disk smooth. . . . . 16. **Hymenoscypha,** p. 146.
Border of disk toothed. . . . . 17. **Cyathicula.**
Spores at length 2 to 4-celled
Ascocarps sessile, rarely compressed at base. . . . . 18. **Belonium.**
Ascocarps stalked, or at least compressed like a stalk
Walls of ascoma waxy; stem short and delicate. . . . . 19. **Belonioscypha.**
Walls of ascoma waxy, thick; stem thick. . . . . 20. **Helotium.**
Spores filiform
Ascocarps sessile. . . . . 21. **Gorgoniceps.**
Ascocarps stalked. . . . . 22. **Pocillum.**
Ascocarps gelatinous gristly, horny when dry. . . . . IV. **Ombrophileæ.**

Of these genera only the five given below have parasitic representatives of economic importance, while only one to two others are parasitic. The rest grow as saprophytes on rotting wood and organic debris in the soil.

Sclerotinia Fuckel (p. 135)

This genus contains several very important pathogens, some of them preying upon a wide range of hosts and causing great loss. A striking feature of the genus is the sclerotium which is black and borne within the host tissue or upon its surface. From the sclerotia after a more or less protracted period the apothecia develop. These are disc-shaped and stalked. The asci are 8-spored; spores elliptical or fusiform, unicellular, hyaline, straight or curved. Some species

possess Botrytis forms (see pp. 141 and 578), others Monilia (see pp. 139 and 558) forms of conidial fructification. In addition to these there may be gonidia, which appear to be degenerate, functionless conidia. In some species there is no known spore form except that in the ascus.

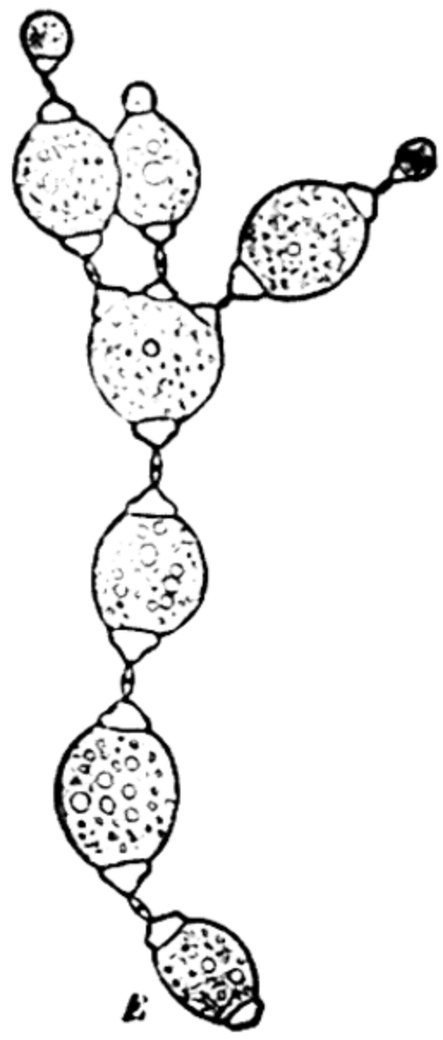


FIG. 91.—S. urnula, moniliform conidia with disjunctors. After Woronin.

S. ledi Now. is of especial interest as the one fungus outside of the Uredinales that exhibits heterœcism.[352]

Many forms found upon separate hosts and presenting slight differences under the microscope, often even no microscopic differences, have been named as separate species. Only long careful culture studies and inoculation experiments will determine which of these species are valid, where more segregation, where more aggregation is needed.

The mere association of Botrytis or Monilia conidial forms with Sclerotinia, in the same host, has repeatedly led to the assumption that such forms were genetically connected. Such assumptions are not warranted. Only the most careful study and most complete evidence justify such conclusions.

The genus contains some fifty species which are divided into two subgenera; Stromatinia Boud., forming sclerotia in the fruits of the host; Eusclerotinia Rehm forming sclerotia in or on stems and leaves of the host.

When conidia are known those of Stromatinia are of the Monilia type and those of Eusclerotinia of the Botrytis type. Each group contains important economic species.

S. fructigena, S. cinerea and **S. laxa.**[20, 21, 25, 291–295]

These forms are perpetuated chiefly by their conidia. The ascus-forms are much less often seen.

When the conidia fall upon the peach, the mycelium develops and penetrates even the sound skin, then rapidly induces a brown rot. The mycelium within the tissue is septate, much branched, and light brown in color. It soon proceeds to form a subepidermal layer and from this the hyphæ arise in dusty tufts of Monilia-form conidiophores and conidia (Fig. 92). The earlier conidia are thin-

walled and short lived, the later ones thicker walled and more enduring.

After some weeks these tufts cease forming and disappear. The mycelium within the fruit persists, turns olivaceous and forms large irregular sclerotioid masses which on the following spring may produce fresh conidia.

These sclerotioid (mummified) fruits under suitable conditions

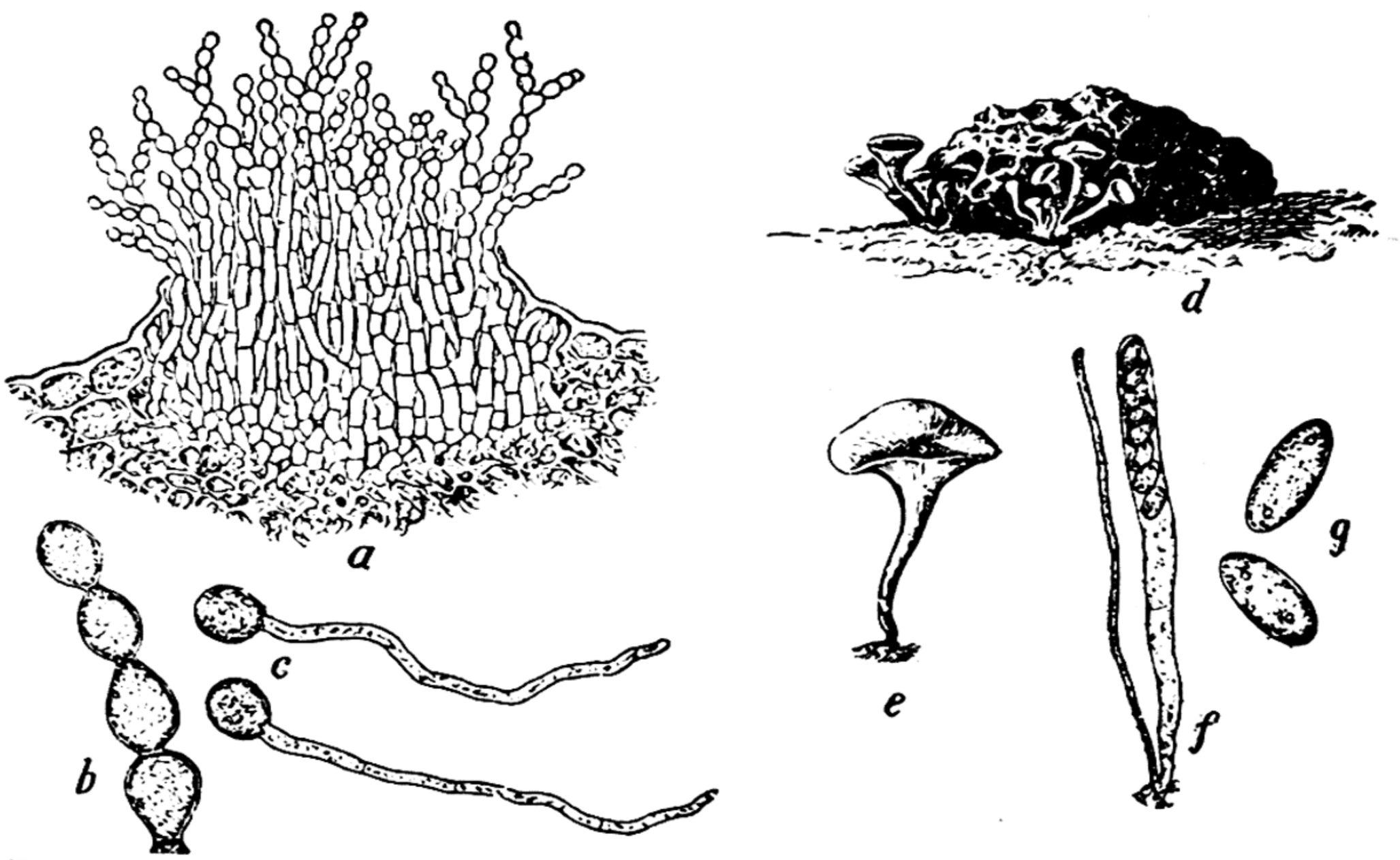


FIG. 92.—Sclerotinia on plum. *a*, section showing a spore pustule and chains of conidia; *b*, part of a spore-chain; *c*, spores germinating; *d*, a mummy plum and ascophores; *e*, an ascophore; *f*, ascus; *g*, mature spores. After Longyear.

in nature, usually at blossom time of the host, can also produce apothecia, a fact first demonstrated by Norton.[22]

These apothecia develop in large numbers from old fruits half buried in soil, and send forth ascospores to aid in infection. The ascospores germinate readily in water and it was proved by Norton that they give rise to a mycelium which produces the characteristic Monilia. Inoculation of ascospores on fruit and leaves also gave positive results in two or three days. The flowers, and through them the twigs, are also invaded by the mycelium which seeks chiefly the cambium and bast. Shot-hole effect is produced on leaves of peach and cherry (Whetzel [23]). Infection is frequently through minute wounds.[24]

On the apple the fungus shows two different modes of development. In some cases the mycelium accumulates under the epidermis without producing spores, becomes dark colored and also causes a darkening of the contents of the host cells, which results in a black spot giving rise to the name black rot. In other cases [25] the mycelium produces a brown rot and abundant conidial tufts, arranged in concentric circles around the point of infection.



FIG. 93.—S. fuckeliana, attachment organ. After Istvanffi.

The form on pomaceous fruits has long been regarded as identical with that on stone fruits; but recently, at least in Europe, they have been distinguished on cultural and morphological grounds [19] (see also [26, 27]), as separate species, the most distinctive character perhaps being the color of the mass of conidia. In a similar way S. laxa Ad & Ruhl. is set aside as a distinct species infecting only apricots.[121]

American mycologists are inclined to doubt the distinctness of the species on drupes and pomes in this country.

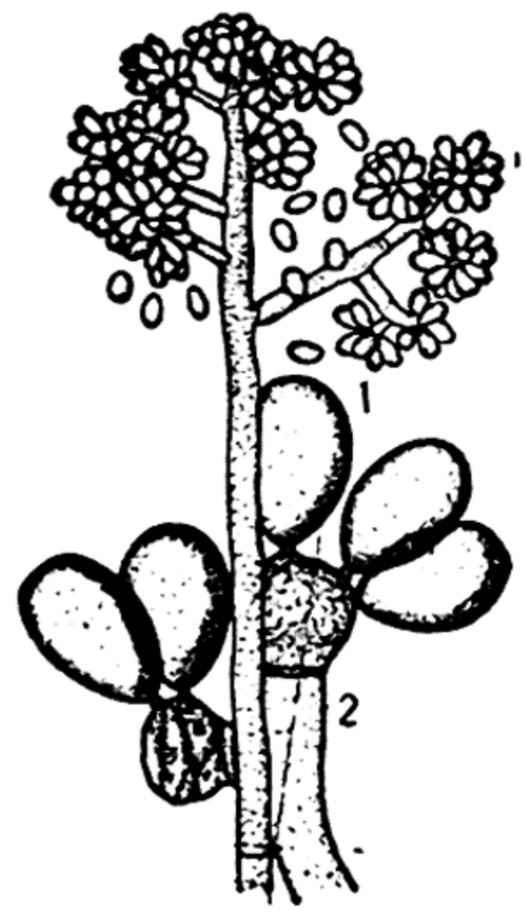


FIG. 94.—Typical conidiophore and conidia of the Botrytis-form of S. fuckeliana. After Smith.

S. fructigena (Pers.) Schr.

Apothecia from sclerotia produced either in or on mummied fruits, 0.5–3 cm. high, stem dark brown, disk lighter, 5–8 or even 15 mm. in diameter; asci 125–215 x 7–10 μ; spores ellipsoidal, 10–15 x 5–8 μ.

Conidia (=Monilia fructigena Pers.). Conidiophores covering the fruits of the host with a dense mold-like growth of light brownish-yellow or ochraceous color; spores averaging 20.9 x 12.1 μ. On stone and pome fruits, especially the latter.

S. cinerea (Bon.) Wor.

Apothecia and asci similar to those of S. fructigena, Conidia (=Monilia cinerea Bon.). Conidiophores covering the fruits with a dense grayish mold-like growth; spores averaging 12.1 x 8.8 μ. On stone and pome fruits, especially the former.

S. linhartiana P. & D.[28] is reported on quince in France. **S. mespili** Schell on medlar. **S. seaveri,** Rehm., conidia = Monilia seaveri, is on Prunus serotina.[218]

S. padi Wor. is found on Prunus padus and Castanea.[22]

It possesses a Monilia-form conidial stage with typical disjunctors, i. e., spindle-shaped cellulose bodies between the conidia which easily break across to facilitate the separation of the conidia.

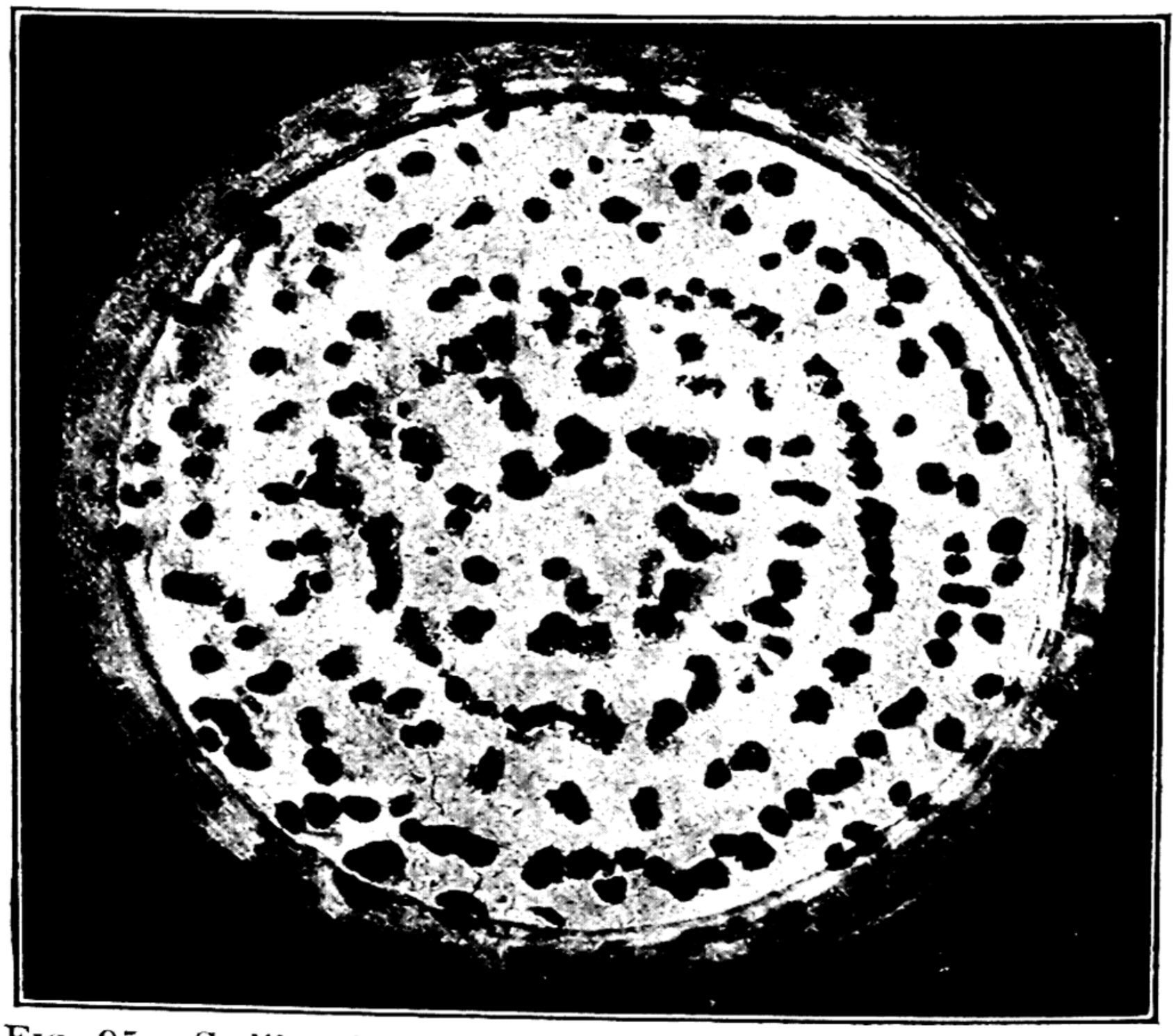


FIG. 95.—S. libertiana. Sclerotia produced in artificial culture. After Stevens and Hall.

S. oxycocci Wor. is found on cranberry. It is unique in that half of the spores in each ascus are larger than the others. The conidial stage is a Monilia.

S. fuckeliana (De Bary) Fcl.[29]

Apothecia in clusters of 2–3 from sclerotia in the leaves, rarely in the fruits, of the host, yellowish-brown, 0.5–4 μ across, stem slender; ascospores 10–11 x 6–7 μ.

Conidia (=Botrytis cinerea Pers., B. vulgaris Fr.). Conidiophores simple or branched, forming dense gray tufts; conidia subglobose, usually minutely apiculate, almost hyaline, 10–12 μ. Fig. 94.

It causes a rot of the grape, much dreaded in Europe, attacking leaves, fruit and stem. The fungus can persist long as a saprophyte in the conidial condition. Sclerotia are borne within the affected tissues. On germination they may either produce the conidia directly or form apothecia. Both ascospores and conidia are capable of infecting the grape but infection is much more certain from a vigorous mycelium (see S. libertiana, p. 142).

Attachment organs, c. f. Fig. 93, which consist of close branch-clusters and seem to be induced by contact of a mycelial tip with any hard substance are present in abundance. Both toxins and digestive enzymes are produced.[29, 36]

Botrytis douglasii on pine is perhaps identical with the conidial form of the last fungus (see p. 140) as may also be the Botrytis of Ward's Lily Disease;[30] the Botrytis causing disease of gooseberries[31] and many others that have been named as distinct species of Botrytis.

S. galanthina Ludwig, close kin to S. fuckeliana, attacks snowdrops. **S. rhododendri** Fisch. occurs on Rhododendron.

The former of these two is supposed to be the ascigerous form of Botrytis galanthina Berk. & Br. but no conclusive proof has been adduced.

S. libertiana Fcl.[32]

Sclerotia from a few millimeters up to 3 cm. in length, black; apothecia scattered, pale, 4–8 mm. or more broad, stem slender; asci cylindric, 130–135 x 8–10 μ, apically very slightly bluish; spores ellipsoid, usually minutely guttulate, 9–13 x 4–6.5 μ; paraphyses clavate.



FIG. 96.—S. libertiana. Sclerotia and apothecia. After Stevens and Hall.

This fungus affects numerous hosts. Among the most important on which it causes serious disease are lettuce,[33, 34, 37, 38] ginseng,[39] cucumber,[35] carrot, potato, parsley, hemp, rape, various bulbs, zinnia, petunia, etc. The white mycelium is found superficially and within the host, especially at places where moisture is retained, as between leaves, at leaf axils, etc., also within plant cavities. Microscopically it consists of long cells branching in a rather characteristic way, Fig. 97. Within

the host's tissue the hyphal threads are thicker, richer in protoplasm, more septate, and much more branched and crooked than outside of the host. Aërial hyphal filaments when they touch a solid repeatedly branch in close compact fashion forming the attachment organs.

At the exhaustion of the food supply and the consequent termination of the vegetative period the mycelium becomes very dense in spots and within these clumps of mycelium the sclerotium forms; at first white, later pink, finally smooth and black (Fig. 95). They are often found in the leaf axils (lettuce), in the pith of stems (carrot), etc. Under some conditions, as on unsuitable nutrient media, gonidia are produced.

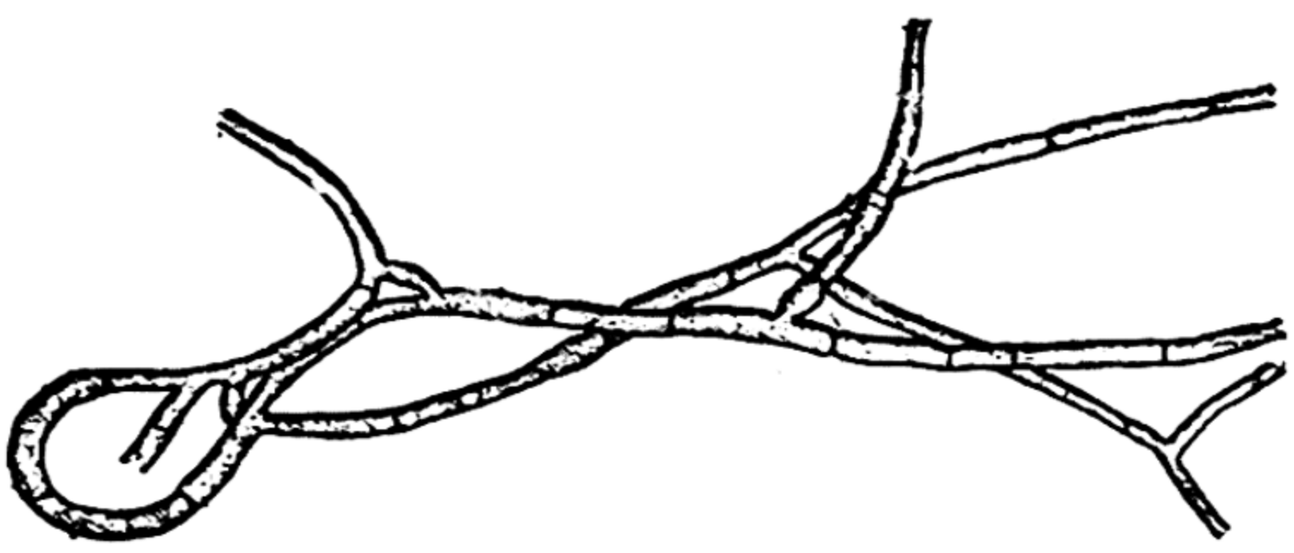


FIG. 97.—Mycelium showing septation and branching. After Stevens and Hall.

The sclerotia can germinate at once or remain dormant for one, perhaps several years. On germination they send forth from 1 to 35 [34] negatively geotropic sprouts which grow to the soil surface unless that be more than about 5 cm. distant. On reaching the light the apex of the sprout begins to thicken and soon develops its apothecium; at first inverted-conidial, soon flat, and finally somewhat revolute. Changes in atmospheric humidity cause the discharge of ascospores in white clouds.



FIG. 98.—S. libertiana, asci and paraphyses. After Stevens and Hall.

The ascospores germinate readily but the resulting mycelium is of such small vigor that it is incapable of parasitism. If the ascospore germinates where it can maintain a saprophytic life until a vigorous mycelium is developed then the mycelium may become parasitic.

Both ascospores and mycelium are comparatively short-lived. The mycelium can migrate but a short distance over soil. No form of conidia except the apparently functionless gonidia is produced. The fungus may be cultivated easily upon almost any medium, corn-meal-agar is especially suitable.

It has been repeatedly claimed that this fungus possesses a

Botrytis conidial stage but the results of much careful work deny this.[34, 40]

Recent tests by Westerdijk [40] indicate the absence of such biologic specialization in regard to hosts as is found in the Erysiphe and elsewhere.



Fig. 99.—Cultures of sclerotinia from tobacco on potato agar, showing sclerotia. After Clinton.

S. nicotianæ Oud. & Kon.[41, 42] parasitizes the leaves and stems of tobacco. It is possibly identical with S. libertiana.

S. trifoliorum Erik.[43–45]

In general this resembles S. libertiana with which it is by some regarded as identical; sufficient evidence has, however, not been adduced to prove them the same. The sclerotia, varying in size from that of a mustard seed to a pea, are found in the decayed tissue, or as larger flat surface sclerotia. No conidia except the functionless gonidia. Unknown on clover.

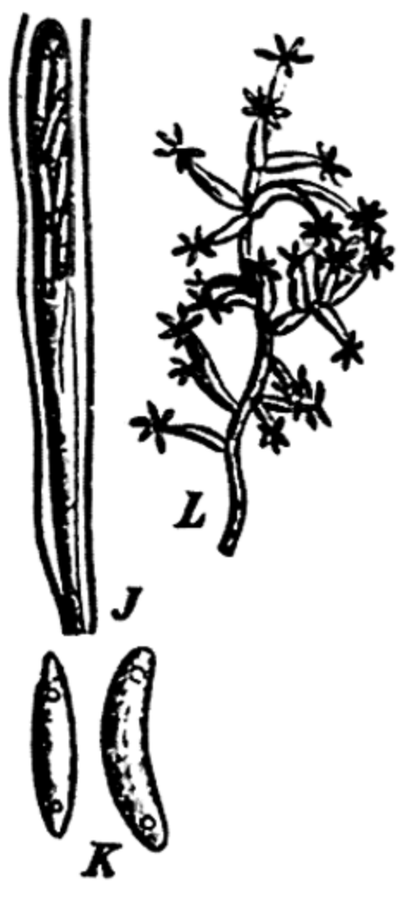


Fig. 100.—C. æruginosum. *J*, ascus; *K*, ascospores; *L*, conidia. After Rehm and Brefeld.

S. bulborum (Wak.) Rehm [46] which is very similar to S. trifoliorum and without known conidia grows on hyacinth, crocus, scilla and tulip. Cross infections between hyacinth and clover have not, however, been successful and the species may be distinct. A sterile form, Sclerotium tuliparum, found on the tulip may also belong here.

S. tuberosa Fcl. is found on wild and cultivated anemones.

Several other species of the genus, among them **S. alni** Maul, **S. betulæ** Wor., **S. aucupariæ** Ludw, **S. crategi** Magn., are found on Ericaceæ, Betulaceæ, Rosaceæ, Gramineæ, etc., but they are not of sufficient economic importance to warrant further notice here.

Chlorosplenium Fries (p. 135)

Ascoma mostly aggregated, small, stalked, smooth without, green; asci cylindric, 8–spored; spores elongate, 1-celled, guttulate, hyaline; paraphyses linear.

The genus consists of some ten species only one of which is of interest here.

C. æruginosum (Oed.) d Not.

The apothecia and mycelium are verdigris-green as is also the

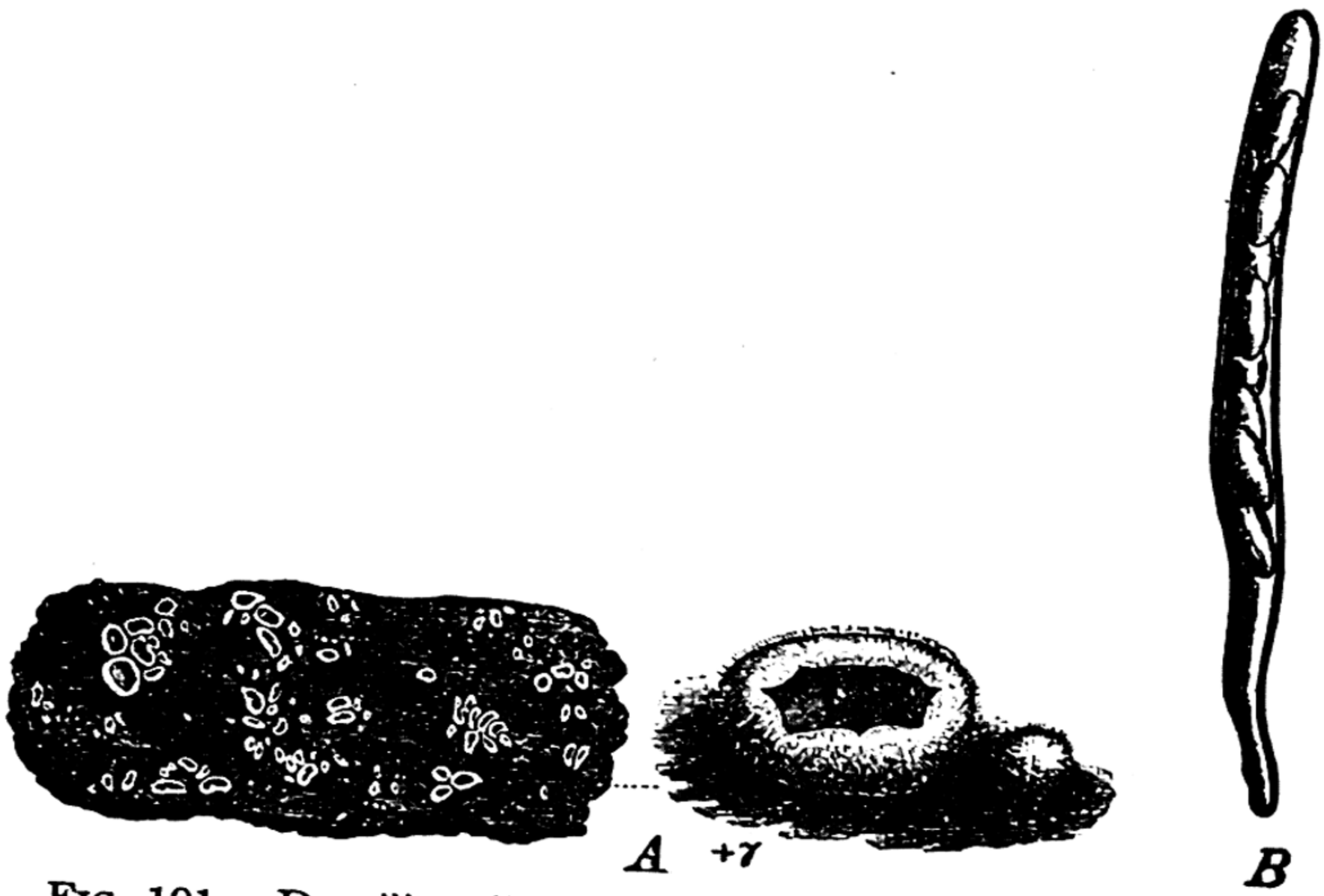


FIG. 101.—D. wilkomii. *A*, natural size and single apothecium enlarged; *B*, an ascus. After Lindau.

wood penetrated by it. The fungus appears to be mainly saprophytic but may be partially parasitic. Fig. 100.

Dasyscypha Fries (p. 135)

This is a genus of some one hundred fifty species, mostly saprophytic but sometimes parasitic on twigs. The apothecia are small, short-stalked or sessile, waxy or membranous, bright colored in the disk, with mostly simple hairs on the outside and margin. Asci cylindrical or clavate, 8-spored; spores ellipsoid or fusiform, hyaline, 1-celled, rarely 2-celled, sometimes guttulate; paraphyses blunt, needle-like.

D. willkommii Hart.[47] causes a serious European larch disease and affects also the pine and fir.

The stromata appear as yellowish-white pustules on the bark soon after its death. Here hyaline conidia are produced on the open surface or in cavities. Apothecia 2–5 mm. broad appear later. The ascospores can infect wounds: the conidia seem to be functionless. The mycelium spreads through the sieve tubes, intercellular spaces, and xylem to the pith.

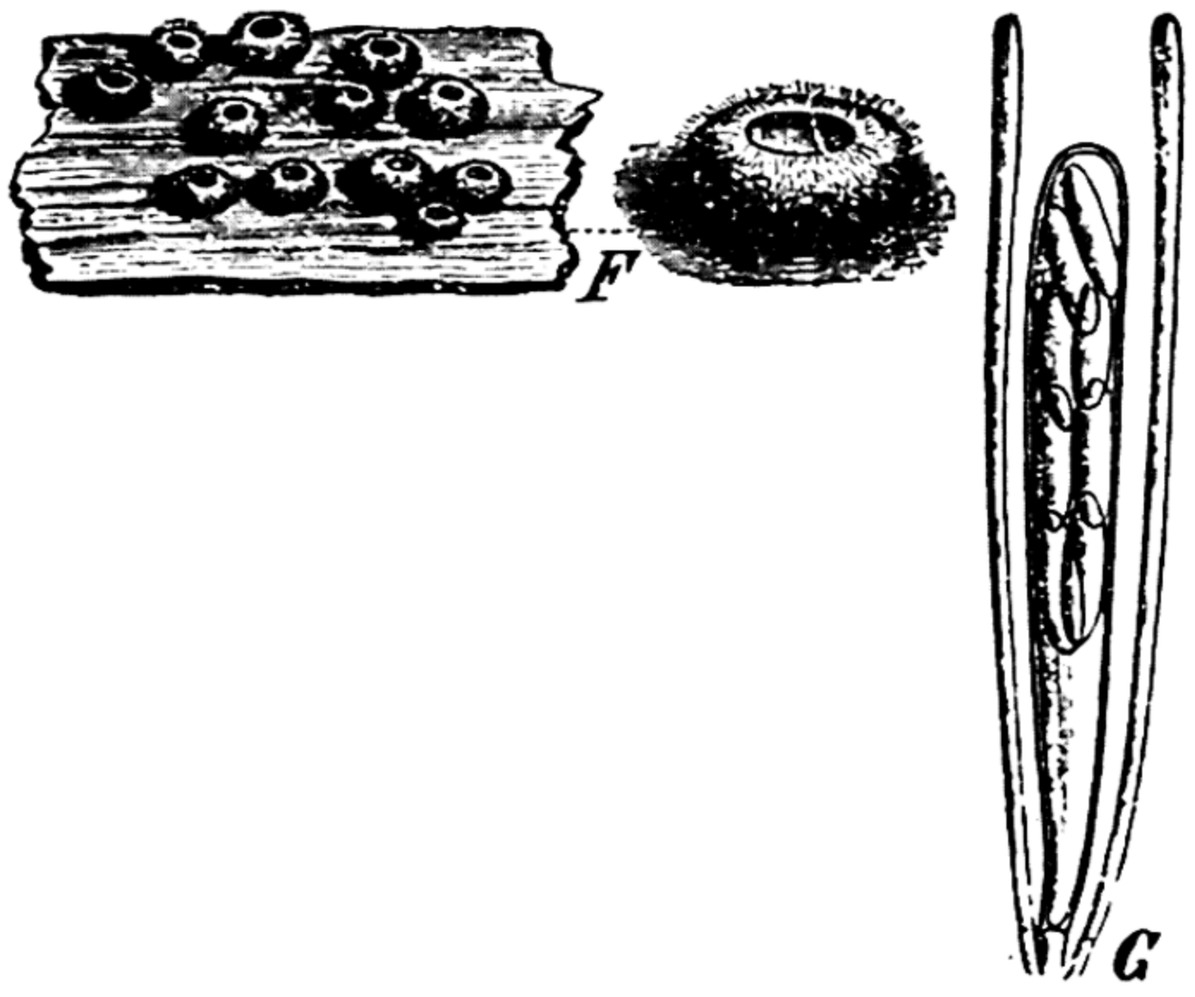


FIG. 102.—Lachnella. *F*, habit sketch; *G*, ascus and paraphyses. After Rehm.

Apothecia short-stalked, yellowish without, orange within; asci 120 x 9 μ; spores 18–25 x 5–6 μ; paraphyses longer than the ascus.

D. resinaria Rehm [48] is a wound parasite much like the above in its effects. It occurs chiefly on spruce and larch but sometimes also on pine, both in Europe and America.

Ascophores upon cankers on branches and trunk of the host, very similar to those of the preceding species but with more evident stipe and paler disk; spores very minute, subglobose, 3 x 2–2.5 μ; conidia 2 x 1 μ.

D. calyciformis (d Wild.) Rehm occurs on several conifers; **D. subtilissima** (Sacc.) on fir and larch; **D. abietis** Sacc. on Picea.

Lachnella Fries (p. 135)

This is similar to the last genus but with the apothecia usually sessile and the spores usually 2–celled at maturity, and in two rows in the ascus. There are about forty species.

L. pini Brun.[49] injures pine twigs. The apothecia are brown outside; the disc reddish-yellow with a white margin.

Ascoma short-stipitate, 5 mm. in diameter, pale brown; disk light

orange-red with a pale margin; asci 109 x 8–9.5 μ; spores 19–20 x 6.5–8.5 μ, hyaline.

Hymenoscypha Fries (p. 136)

This genus of over two hundred species is mainly saprophytic, one species only in its conidial stage being parasitic.

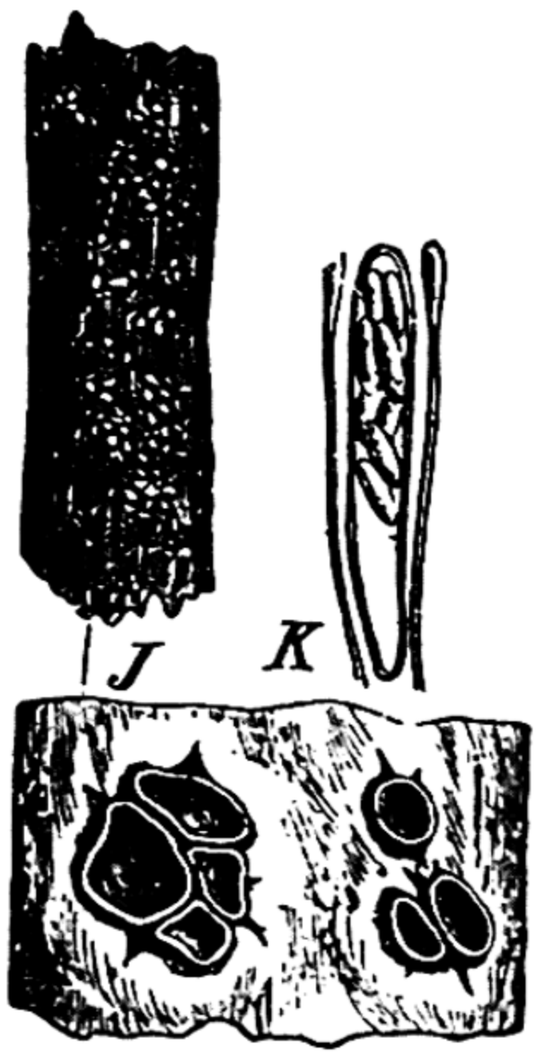


FIG. 103.—Hymenoscypha. *J*, habit sketch; *K*, ascus and paraphyses. After Rehm.

Ascoma sessile or short-stipitate, usually smooth; asci cylindric to globoid, 8–spored; spores elliptic, blunt to pointed, hyaline; paraphyses filamentose, apically enlarged, hyaline.

H. tumulenta P. & D.[50] in its conidial stage as Endoconidium, affects rye grain causing it to shrivel and assume poisonous properties. The conidia are borne endogenously in the terminal branches of the hyphæ and escape through an opening in the end of the branch.

Mollisiaceæ (p. 134)

Ascocarp free from the first or sunken in the substratum and later erumpent, at first more or less globose, becoming flattened; asci 8-spored, opening by a slit; spores hyaline, 1 to many-celled; paraphyses slender. Above four hundred species.

KEY TO GENERA OF **Mollisiaceæ**

Ascocarp fleshy, waxy, rarely membranous. I. Mollisieæ.

Ascocarps not sunken in the substratum
  Ascocarps on a visible, often radiate mycelium
    Spores elongate, often fusiform, 1-celled ..... 1. **Tapesia.**
    Spores filiform, many-celled. ..... 2. **Trichobelonium.**
  Ascocarps not seated on a visible mycelium
    Spores 1-celled
      Spores spherical. ..... 3. **Mollisiella.**
      Spores elongate. ..... 4. **Mollisia.**

Spores becoming 2-celled.	5. **Niptera.**
Spores elongate filiform, 4-celled. . . .	6. **Belonidium.**
Spores filiform many-celled.	7. **Belonopsis.**
Ascocarps at first sunken in the substratum, later erumpent	
Ascocarps bright colored, only slightly erumpent	
Spores ellispoid or elongate, rounded, 1-celled.	8. **Pseudopeziza,** p. 147.
Spores becoming many-celled.	9. **Fabræa,** p. 149.
Ascocarps dark colored, at length strongly erumpent	
Spores ellipsoid or fusiform, 1-celled	
Ascocarps bristly externally and on the margin.	10. **Pirottæa.**
Ascocarps externally smooth, the margin at most merely shredded.	11. **Pyrenopeziza.**
Spores many-celled by transverse septa.	12. **Beloniella.**
Ascocarps gelatinous gristly, horny when dry.	II. **Calloricæ.**

Of this large number of genera only two are important pathogens, several of the others are parasitic on non-economic hosts while others are saprophytic chiefly on decaying woody parts.

Pseudopeziza Fuckel

The genus comprises some ten species, all parasitic on leaves, several of them upon economic plants causing serious disease. The very small apothecium develops subepidermally breaking through only at maturity, light colored; spores 1-celled, hyaline, in two ranks in the ascus; paraphyses somewhat stout, hyaline. Conidial forms are found in Glœosporium, Colletotrichum and Marssonia.

P. medicaginis (Lib.) Sacc.[51, 52]

The epiphyllous apothecia are in the older leaf spots, subepidermal at first but eventually breaking through.

Apothecia saucer-shaped, light colored, fleshy; asci clavate;

spores hyaline, 10–14 μ long; paraphyses numerous, filiform. A Phyllosticta thought to be its conidial stage has been reported.[53]

On dead spots in leaves of alfalfa and black medick.

P. trifolii (Bernh.) Fcl.

This is closely related to, perhaps identical with, the last species. Sporonema (Sphæronæma) phacidioides Desm. is supposed to be its conidial form. This conidial stage has not however, been observed on alfalfa.

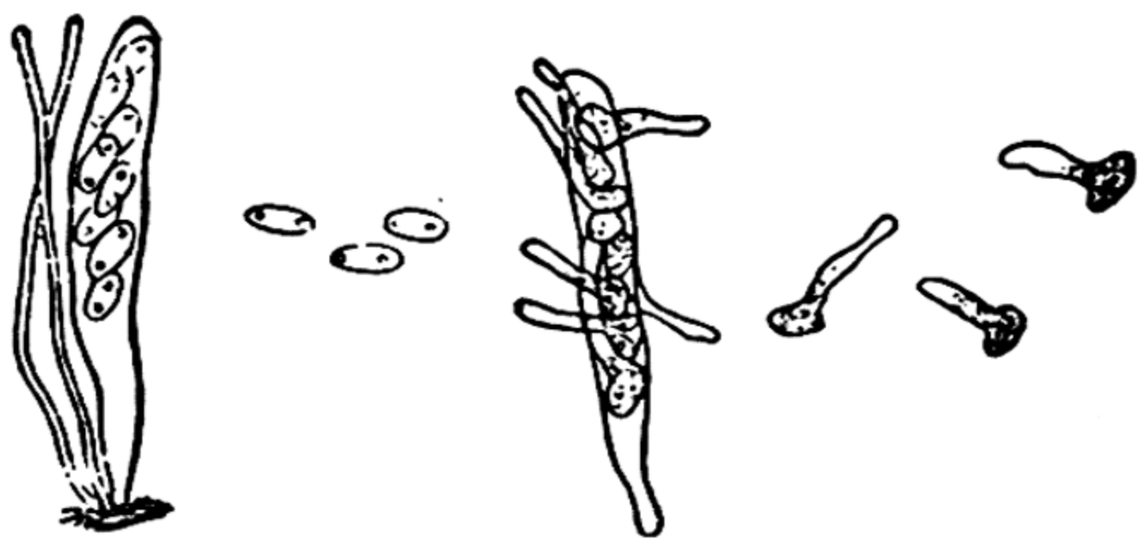


FIG. 104.—P. trifolii. Ascus and paraphyses; germinating spores. After Chester.

Ascocarps mostly epiphyllous, on dead spots, averaging 0.5 mm. broad, yellowish or brownish; spores elliptic 10–14 x 5–6 μ.

Conidia in cup-shaped pycnidia which are numerous, small, light brown; disk cinnamon-colored; conidia ovoid-oblong, 5 μ, bi-guttulate.

P. tracheiphila Müller-Thurgau [54] is found upon the grape in Europe.

P. salicis (Tul.) Pot. occurs on Salix. Conidia (=Glœosporium salicis).

P. ribis, Kleb.[55-57]

Apothecia appear in the spring on dead leaves of the previous season; saucer-shaped, fleshy, somewhat stalked; asci clavate, spores hyaline, ovoid; paraphyses simple or branched, slightly clavate, rarely septate.

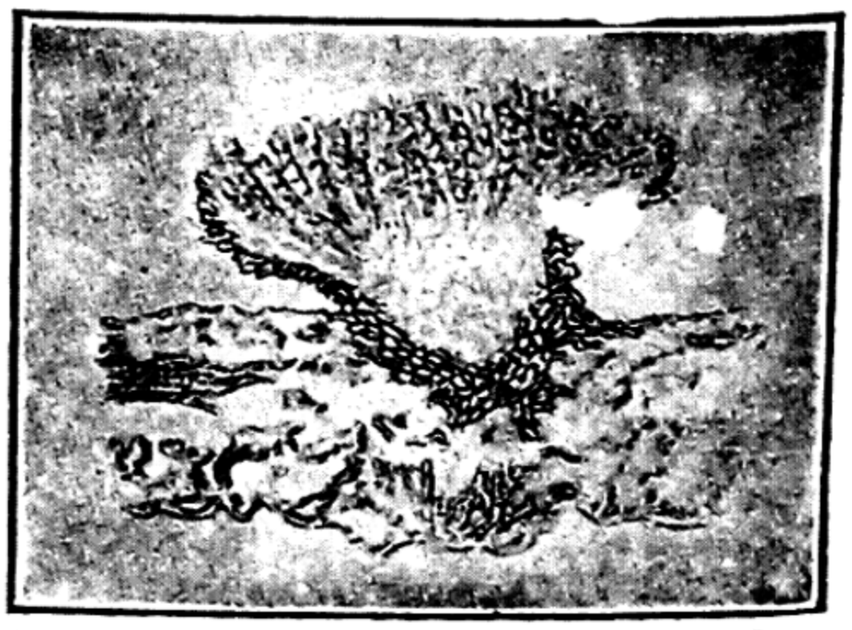


FIG. 105.—P. ribis. Apothecium in section. After Klebahn.

Conidial phase (=Glœosporium ribis) on the leaves of the host forming an abundant amphigenous infection; acervuli stromatic; conidiospores commonly 19 x 7 μ, varying from 12–24 x 5–9 μ, escaping in gelatinous masses.

On red and white currants less commonly on black currants and gooseberries both in Europe and America.

The ascigerous stage of this fungus was demonstrated by Klebahn [57] in 1906 to be genetically connected with what had been

earlier known as Glœosporium ribis (Lib.) Mont. & Desm. Old leaves bearing the latter fungus were wintered out-doors in filter paper and in the spring were found with this ascigerous stage. The ascospores were isolated, grown in pure culture and typical conidia were produced. The ascospores also infected the host leaves successfully producing there the typical Glœosporium. The conidial stage is the only one ordinarily seen. The acervuli are subepidermal elevating the epidermis to form a pustule which eventually ruptures and allows the spores to escape as a gelatinous whitish or flesh-colored mass. The spores are curved and usually larger at one end than at the other.

Fabraea Saccardo (p. 147)

This is a genus of some ten species of small leaf parasites which much resemble Pseudopeziza but differ from it in its 2 to 4-celled spores.

F. maculata (Lev.) Atk.[58–60]

The perfect stage is common on pear and quince leaves which have wintered naturally. When such leaves are wet the white 8-spored asci may be seen crowding through the surface in small elliptical areas. The apothecium is paraphysate; the spores hyaline and 2-celled.

Conidial form (=Entomosporium maculatum) on leaves and fruits; acervuli, black, subepidermal, the epidermis breaking away to expose the spore mass; spores hyaline 18–20 x 12 μ, 4-cells in a cluster, the lateral cells smaller, depressed; stipe filiform 20 x 0.75 μ; the other cells with long setæ.



FIG. 106.—F. maculata. 1, acervulus of conidial stage in section; 3, spores. After Southworth.

Atkinson [59] proved the connection of the ascigerous with the conidial form by cultivating the conidia from the ascospores. The conidial form is very common and destructive on pear and quince leaves and fruit. The mycelium which abounds in the diseased spot is hyaline when young, dark when old. It collects to form a

thin subcuticular stroma. On this the spores are produced on short erect conidiophores, Fig. 106; eventually the cuticle ruptures and the spores are shed. The spores germinate by a tube which arises from near the base of a bristle.

F. mespili (Sor.) Atk. on medlar with the conidial form Entomosporium mespili (D. C.) Sacc. is perhaps identical with the above. There are only minor and uncertain differences in the conidial stage.[59] Sorauer by inoculation with conidiospores produced on pear typical spots which bore mature pustules after an interval of about a month. He referred the fungus to the genus, Stigmatea Fries. See p. 243.

Cenangiaceæ (p. 134)

Ascoma at first buried, later erumpent, on a stroma, dark, with a rounded or elongate disk; asci 8-spored; spores long or filiform, 1 to many-celled, often muriform, hyaline or dark; paraphyses branched forming a complete epithecium. About two hundred fifty species.

Key to Subfamilies and Genera of Cenangiaceæ

Ascocarps coriaceous, corneous or waxy when fresh	I. **Dermateæ.**
Ascocarps without a stroma, at first immersed.	
Spores 1-celled	
Ascocarps externally bright colored, downy	1. **Velutaria.**
Ascocarps externally dark	
Ascocarps smooth; spores hyaline	2. **Cenangium,** p. 151.
Ascocarps downy; spores colored	3. **Schweinitzia.**
Spores 2 to 4-celled, elongate	
Spores hyaline	
Spores always 2-celled; ascocarp smooth	4. **Cenangella.**
Spores 2 to 4-celled; ascocarps downy externally	5. **Crumenula.**
Spores at length brown or black	
Disk elongate with a thick rim	6. **Tryblidiella.**
Disk rounded	
Rim thin; spores 2-celled	7. **Pseudotryblidium.**
Rim involute; spores 4-celled	8. **Rhytidopeziza.**

Spores many-celled, filiform	9. **Gordonia.**
Ascocarps springing from a more or less developed stroma	
Spores 8, not sprouting in the ascus	10. **Dermatea**, p. 152.
Spores sprouting in the asci which become filled with conidia	11. **Tympanis.**
Ascocarps gelatinous when fresh	II. **Bulgarieæ.**
Ascocarps sessile or stalked, with smooth, saucer-shaped disc	
Spores 1-celled, round	12. **Pulparia.**
Spores 1-celled, elongate	
Ascocarps soft, gelatinous inside, sessile, thin	13. **Bulgariella.**
Ascocarps soft, gelatinous, stalked, thick	14. **Bulgaria,** p. 152.
Ascocarps watery gelatinous	15. **Sarcosoma.**
Spores 2-celled	
Spores unequally 2-celled rounded at the ends	16. **Paryphedria.**
Spores elongate, acute at the ends	17. **Sorokina.**
Spores filiform	18. **Holwaya.**
Spores muriform	19. **Sarcomyces.**
Ascocarps with convolute tremelliform discs	
Spores 1-celled, hyaline	20. **Hæmatomyces.**
Spores muriform, blackish	21. **Hæmatomyxa.**

With few exceptions these genera are so far as known saprophytes though it is probable that further study will reveal some of them as weak parasites or possibly as destructive ones.

Cenangium Fries (p. 150)

Parasitic or saprophytic chiefly in bark, the apothecium developing subepidermally and later breaking through to the surface; sessile, light colored without, dark within; asci cylindric-globoid, 8-spored; spores ellipsoid, 1 or rarely 2-celled, hyaline or brown, in one row; paraphyses colored. About seventy species.

C. abietis (Pers.) Rehm.[61] has caused serious epidemics upon pine in Europe and America.

Ascoma dark-brown, erumpent, clustered; spores ellipsoid, 10–12 x 5–7 μ.



FIG. 107.—Cenangium, habit sketch, asci and paraphyses. After Tulasne.

Conidia (=Brunchorstia destuens Erikss.) in pycnidia which are partially embedded in the host, the smaller simple, the larger compound, 1–2 mm. in diam.; spores 30–40 x 3 μ, tapering-rounded at each end, 2 to 5-septate.

A second conidial phase (=Dothichiza ferruginosa Sacc.) has simple spores.

C. vitesia occurs in conidial form as Fuckelia on Ribes.

Dermatea Fries (p. 151)

A genus of over sixty species some of them parasitic. In many species conidia in pycnidia are known.

Ascocarps scattered or clustered, stromate, sessile or not, black or brown; asci small, thick-walled, 8 or 4-spored; spores ellipsoid or spindleform, 1-celled, becoming 4 to 6-celled, brown, 2-ranked; paraphyses septate, apically enlarged and colored.

D. carpinea (Pers.) Rehm. is a wound parasite on the hornbeam and beech; **D. cinnamomea** (Pers.) Rehm. on oaks; **D. acerina** Karst, on maple (Acer pseudoplatanus); all in Europe.

D. prunastri (Pers.) Fr., with its conidial form Sphæronema spurium Fr. is found on Bark of various species of Prunus, in Europe and America.

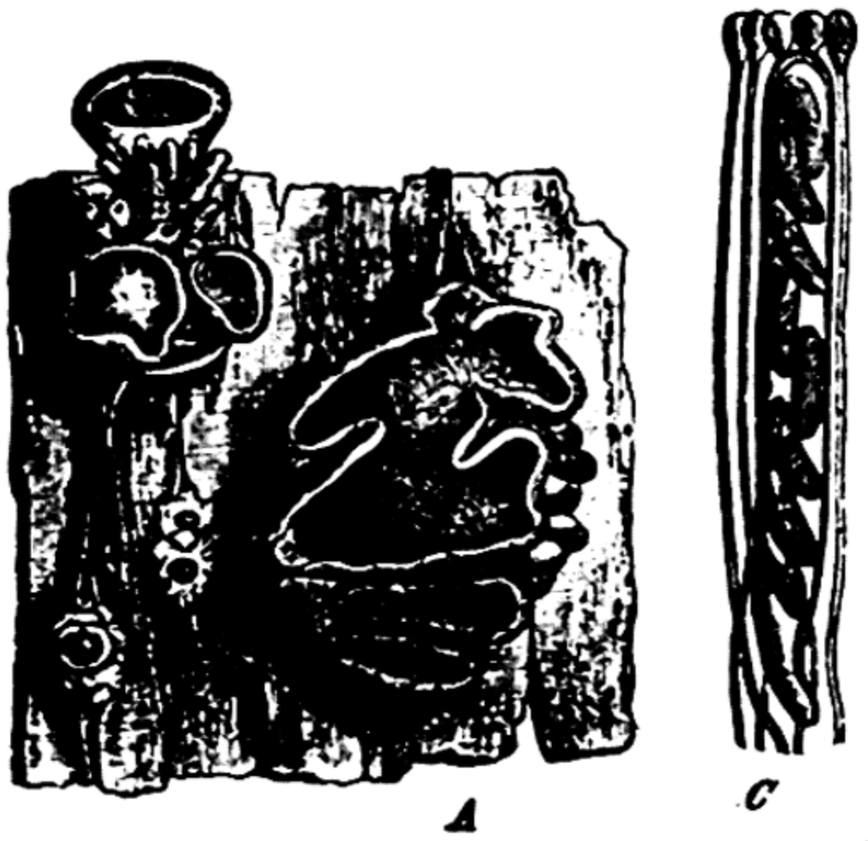


FIG. 108.—Dermatea. *A*, habit sketch; *C*, ascus and paraphyses. After Tulasne and Rehm.

Bulgaria Fries (p. 151)

The gelatinous apothecium is rather large and dark colored; asci 4 to 8-spored; spores 1-celled, elongate, brown.

There is one species worthy of mention.

B. polymorpha (Oed.) Wett.[62, 63] is a common saprophyte on bark. It is said to sometimes become parasitic. Ascocarps black, stipitate; disk scarcely cupped, ranging up to 4 cm. in diameter although usually smaller.

Caliciaceæ (p. 134)

Stroma more or less thalloid, with or without algal cells, often rudimentary and inconspicuous; ascoma more or less globoid, stipitate; the apex of the ascus dissolving before the spores are matured, thus allowing the hyaline unripened spores to escape and mature afterwards.

This small family (less than one hundred twenty-five species) contains the only lichens of phytopathological importance, unless the foliose lichens which sometimes appear on poorly kept fruit trees be considered.

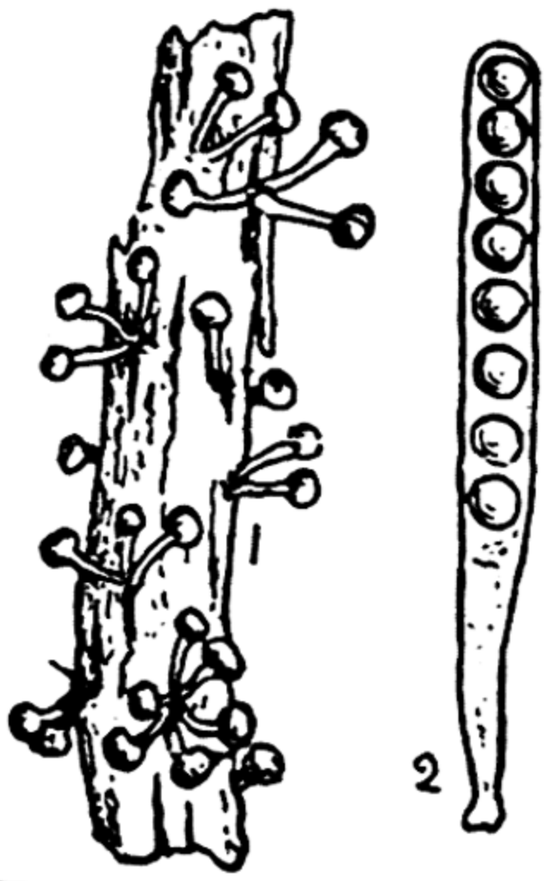


FIG. 109.—C. pallida on Grape Root. 2, Ascus. After Massee.

KEY TO THE GENERA OF Caliciaceæ

Ascoma with a long stalk	
Spores spherical, or subspherical	
Spores colorless or only slightly colored.	1. **Coniocybe,** p. 153.
Spores brown or brownish.	2. **Chænotheca.**
Spores elongated, septate	
Spores elongate elliptic or egg-shaped, usually two-celled.	3. **Calicium.**
Spores elliptic to spindle-form, 4 to 8-celled.	4. **Stenocybe.**
Ascoma short stalked	
Spores 2-celled.	5. **Acolium.**
Spores globose, 1-celled.	6. **Sphinetrina.**

Coniocybe pallida (Pers.) Fr. is generally distributed throughout Europe and America, commonly on the bark of various forest trees and upon the crown and roots of the grape. The parasitic

nature of the fungus is in doubt.[22] The entire height of the ascocarp is 2 mm.; head white, then grayish brown; asci cylindric, 8-spored; spore tinged with brown, 4–5 μ in diameter. The species as a pathogen is usually referred to as Rœsleria hypogæa Thüm & Pass. and given a place in the Geoglossaceæ; but Durand [64] follows Schröter in excluding the species from that family. Fig. 109.

Phacidiales (p. 124)

This order, comprising some six hundred species only a few of which are pathogens, is characterized as follows: mycelium well developed, much branched, multiseptate; ascocarps fleshy or leathery, free or sunken in the substratum or in a stroma, rounded or stellate, for a long time enclosed in a tough covering which at maturity becomes torn; paraphyses usually longer than the asci, much branched, forming an epithecium.

Key to Families of Phacidiales

Ascocarps soft, fleshy, bright colored.....	1. **Stictidaceæ, p. 154.**
Ascocarps leathery or carbonous, always black	
Ascocarps at first sunken, later strongly erumpent, hypothecium thick.	2. **Tryblidiaceæ, p. 155.**
Ascocarps remaining sunken in the substratum, hypothecium thin, poorly developed.....	3. **Phacidiaceæ, p. 155.**

Stictidaceæ

The members of this family (about twenty genera and two hundred fifty species) are usually considered saprophytes, although one species of Stictis has recently been described as a parasite.

Stictis Persoon

Perithecia sunken, pilose, at length erumpent; asci cylindric, containing eight filiform, multiseptate spores; paraphyses filiform,

richly branched apically. Of the seventy or more species of the genus only one, **S. panizzei** d Not., originally described from fallen olive leaves in Italy, has been charged with producing disease.[65] It has within the last few years become very destructive in Italy.

The **Tryblidiaceæ,** with six genera and some seventy species, are likewise chiefly saprophytes with the possible exception of the two genera Heterosphæria and Scleroderris.[19] The former occurs on umbellifers while the latter may contain the perfect stage of certain currant and gooseberry fungi (Mastomyces and Fuckelia) of Europe as well as a European parasite of the willow.

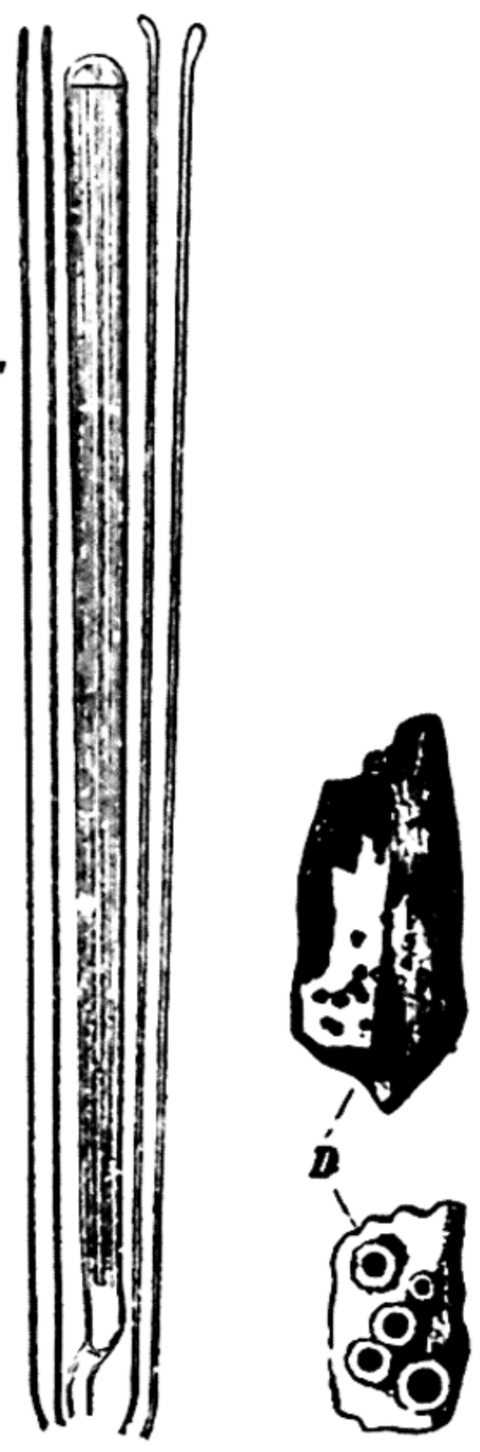


FIG. 110.—Stictis. *D*, habit sketch, *E*, ascus and paraphyses. After Rehm

Phacidiaceæ (p. 154)

Apothecia sunken, more or less erumpent, disk-like or elongate, single or grouped, leathery or carbonous, black, firm, opening by lobes or rifts.

KEY TO GENERA OF Phacidiaceæ

Apothecia not inseparably united to the substratum.	I. **Pseudophacidieæ.**
Spores elongate, hyaline, 1-celled.	1. **Pseudophacidium.**
Spores elongate, spindle-form or filiform, multicellular.	
Spores elongate to filiform, not muriform	
Apothecia rounded, opening by a rounded mouth	
Spores elongate or spindle-form paraphyses, none.	2. **Dothiora,** p. 156.
Spores elongate-globoid, 2-celled; paraphyses present.	3. **Rhagadolobium.**

Spores needle-like; paraphyses present..... 4. **Coccophacidium.**
Apothecia elongate; opening by a slit..... 5. **Clithris,** p. 157.
Spores elongate, muriform, with paraphyses ..... 6. **Pseudographis.**
Apothecia firmly united to the substratum. II. **Phacidieæ.**
Apothecia separate, no stroma
Spores ellipsoid or globoid, 1 to 4-celled
Spores 1-celled
Apothecia rounded
Paraphyses not forming an epithecium. ..... 7. **Phacidium,** p. 157.
Paraphyses forming an epithecium..... 8. **Trochila,** p. 157.
Apothecia irregular, elongate, opening by an irregular mouth..... 9. **Cryptomyces,** p. 158.
Spores 2 to 4-celled
Spores hyaline
Apothecia rounded, spores 2 to 4-celled..... 10. **Sphæropeziza.**
Apothecia elongate, spores 2-celled..... 11. **Schizothyrium.**
Spores brown..... 12. **Keithia.**
Spores filiform or needle-like, 1 to many-celled..... 13. **Coccomyces.**
Apothecia collected on a stroma, opening elongate
Spores 1-celled, hyaline
Spores ovate..... 14. **Pseudorhytisma.**
Spores filiform or needle-like. ..... 15. **Rhytisma,** p. 158.
Spores 2-celled
Spores hyaline..... 16. **Marchalia.**
Spores brown..... 17. **Cocconia.**

Dothiora Fries (p. 155)

There are about ten wood-inhabiting species. Ascocarp at first sunken in the substratum, later irregularly erumpent; disk black; asci clavate, 8-spored; spores elongate or spindle-form, many-

celled or muriform, hyaline or slightly yellowish; paraphyses wanting.

D. virgultorum Fr. grows on birch.

Clithris Fries (p. 156)

A small genus of about twenty species found on wood and bark; mainly saprophytes.

Ascoma sunken, then erumpent, elongate, with lip-like margins, dark colored; asci clavate, 8-spored, often blunt pointed; spores linear or spindle-shaped, multicellular; paraphyses filiform, coiled apically, hyaline.

C. quercina (Pers.) Rehm. is found on oak branches and is perhaps identical with **C. aureus** Mass. on willows. **C. juniperus** is found on living juniper.



FIG. 111.—Clithris. Ascus with spores and paraphyses. After Rehm.

Phacidium Fries (p. 156)

Over seventy species chiefly on leaves or herbaceous stems. Ascoma single, flattened, soon becoming lenticular, breaking open by an irregular rift; asci clavate, 8-spored; spores ovate or spindle-shaped, hyaline, 1-celled; paraphyses thread-like, hyaline. Conidial form probably in part = Phyllachora.

P. infestans Karst. is a parasite on pine leaves.

Trochila Fries (p. 156)

Perithecia sunken and closed, later erumpent, black, leathery; asci clavate 8-spored; spores long, hyaline, 1-celled; paraphyses filamentose forming an epithelium. Fig. 112.

T. popularum Desm. is thought by Potebnia [296] and Edgerton [297] to be the ascigerous form of Marssonia castagnei D. & M.

T. craterium is the ascigerous form of Glœosporium paradoxum. See p. 541.

Cryptomyces Greville (p. 156)

A genus of some ten species living on wood or leaves, forming large black blotches.

Ascoma sunken in the substratum, flattened, erumpent, irregular in outline, coal black; asci clavate, 8-spored; spores elongate, 1-celled, paraphyses filiform.

C. maximus (Fr.) Rehm [19] is a parasite on willow and dogwood twigs in Europe and America, forming large carbonous areas under the bark.

Rhytisma Fries (p. 156)

To Rhytisma belong about twenty-five species which cause very conspicuous, though but slightly injurious, black leaf-spots. The spots which are white within, are due to sclerotial cushions formed in the host tissue. Thickening of the leaf occurs in the infected part. One-celled conidia (Melasmia form) are abundantly produced in pycnidia early in the season, followed by sclerotium formation. Much later, usually well into winter or the following spring, the apothecia appear. Besides the asco-spore-producing forms several species of which the asco-spores are unknown have been referred here.



FIG. 112. — Trochila. Ascus and paraphyses. After Rehm.

Ascoma on a sclerotial stromatic layer, which is black above, white within; ascocarps elongate, opening by a lip-like slit; asci clavate, often blunt pointed, 8-spored; spores filiform or needlelike, hyaline, mostly 1-celled, lying parallel and lengthwise of the ascus; paraphyses filiform, hyaline, often arched above

R. acerinum (Pers.) Fr.

The spot is at first yellow and thickened and in this stage bears numerous conidia upon short conidiophores. The apothecia ripen in spring and rupture by numerous irregular fissures which follow the ridges of the wrinkled surface. Klebahn secured infection by ascospores resulting in three weeks in yellow spots and in eight weeks in conidiospores. The conidia are supposed to aid in

spreading the fungus during the summer though they have not yet actually been observed to germinate or to cause infection.

Apothecia radiately arranged on the stroma which is about 0.5–1.5 cm. across; asci 120–130 x 9–10 μ; spores large, 65–80 x 1.5–3 μ; paraphyses numerous, incurved or hooked.

Conidia (=Melasmia acerina Lev.) preceding the asci, producing numerous small, hyaline, 1-celled spores in an extended hymenial layer.

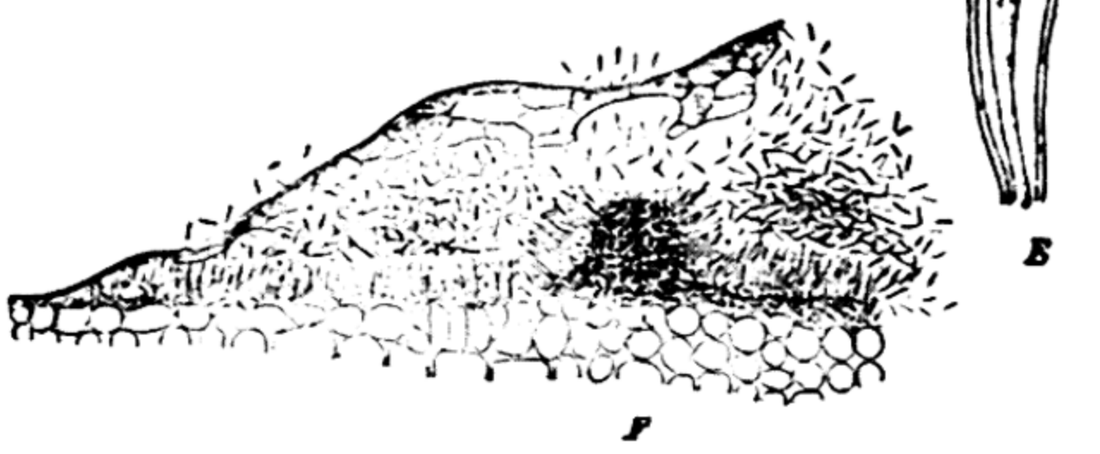


FIG. 113.—R. acerinum. *F*, conidial layer; *E*, ascus and paraphyses. After Tulasne.

On various species of maple, apparently consisting of races since in different localities the host differs without a crossing over of the fungus.

R. punctatum (Pers.) Fr. also occurs on maple, especially Acer pseudoplantanus. It may be distinguished from the preceding by its small, speck-like stromata.

R. salicinum (Pers.) Fr. is found on willow in Europe and America. It is quite similar in external appearance to R. acerina except for the smaller average size of the spots.

R. symmetricum Müll. is another willow inhabiting species. The apothecia are amphigenous and are said to mature in autumn on the still live leaves.

Other species are common especially on various Ericaceæ and Coniferæ in Europe and America.

Hysteriales (p. 124)

Small species with elongated, black, covered apothecia which open by a long narrow slit exposing the hymenium; asci 8-spored; spores usually long and slender. Some few are leaf parasites but most are wood saprophytes. Pycnidia are found in some species. The order serves as a bridge between the Discomycetes and the Pyrenomycetes. About four hundred species.

Key to Families of Hysteriales

Ascocarps immersed; walls of the ascocarps connate with the membranous covering..... ..... 1. **Hypodermataceæ, p. 160.**
Ascocarps at first immersed, erumpent, walls free
Walls membranous or coriaceous, black. 2. **Dichænaceæ, p. 162.**
Walls thick, almost corky, gray or black..... 3. **Ostropaceæ.**
Ascocarps from the first free
Walls carbonous, black; shield-shaped, round, oval or more commonly linear ..... 4. **Hysteriaceæ, p. 163.**
Walls membranous or horny, brown, ascocarps vertical, clavate..... 5. **Acrospermaceæ.**

The third and fifth families contain no pathogens.

Hypodermataceæ

Ascocarp flattened, rounded or elongate, rarely branched, united to the substratum; opening by a slit; asci 4 to 8-spored; paraphyses apically branched, the branches forming an epithecium, or hooked or crimped. About fifty species, chiefly saprophytes.

Key to Genera of Hypodermataceæ

Spores elongate, rather broad
Spores 1-celled or by cross walls 2 to many-celled
Spores 1-celled
Asci 8-spored, spores spindle-form
Spores hyaline..... 1. **Henriquesia.**
Spores brown. . . . . 2. **Farlowiella.**
Asci 4-spored, spores hyaline..... 3. **Hypodermella, p. 161.**
Spores 2-celled, hyaline
Apothecium black. . . . . 4. **Hypoderma, p. 161.**
Apothecium red. ..... 5. **Angelinia.**

Spores 4 to many-celled, spindle-form	
Spores 4-celled, mostly hyaline.	6. **Gloniella.**
Spores 4 to many-celled, brown	7. **Rhytidhysterium.**
Spores muriform, hyaline.	8. **Hysteropsis,** p. 161.
Spores filiform, 1-celled.	9. **Lophodermium,** p. 161.

Of these genera only four are important here.

Hypodermella Tubeuf (p. 160)

This differs from the next genus in its pyriform unicellular spores; asci 4-spored. Two species, both European and economic.

H. larius Tub. affects larch needles in Europe. [66]

H. sulcigena Link is on pine needles.

Hypoderma De Candolle (p. 160)

Apothecia oblong, opening through a thin black cover by a long fissure; asci 8-spored; spores cylindrical or fusiform, 2-celled at maturity; paraphyses hooked at the end.

H. desmazieri Duby,[298] on pine needles in America and Europe.

Amphigenous; asci broadly clavate, sessile; spores hyaline, linear-elliptic, obtuse and 2-rowed.

H. laricis, H. strobicola, H. pinicola, produce premature leaf fall in various conifers.

Hysteropsis Rehm

Asci clavate, 8-spored; spores hyaline, muriform; paraphyses branched, forming an epithecium.

H. brasiliensis occurs on cacao trees.

Lophodermium Chevall

Spores long, thread-like, continuous; conidiospores in pycnidia.

L. pinastri (Schr.) Chev. occurs in Europe [67] and America on Pinus sylvestris especially on young plants causing the leaves to fall. The first year pycnidia only are formed, the asci not appearing until the second year.[299]

Ascocarps scattered on the leaf, shining black, up to 1 mm. long; asci clavate, 8-spored; spores nearly as long as the ascus, 90–120 x 1.5 μ. Conidia cylindric, hyaline, continuous, 6–8 x 1 μ.

L. brachysporum Rost.

Perithecia epiphyllous; asci cylindric, short-stalked, apex rounded, 120 x 20–25 μ, 8-spored; paraphyses bacillar, apex curved; spores oblong, 1-rowed, hyaline, 28–30 x 9–10 μ.

It is common on pine leaves.[299]

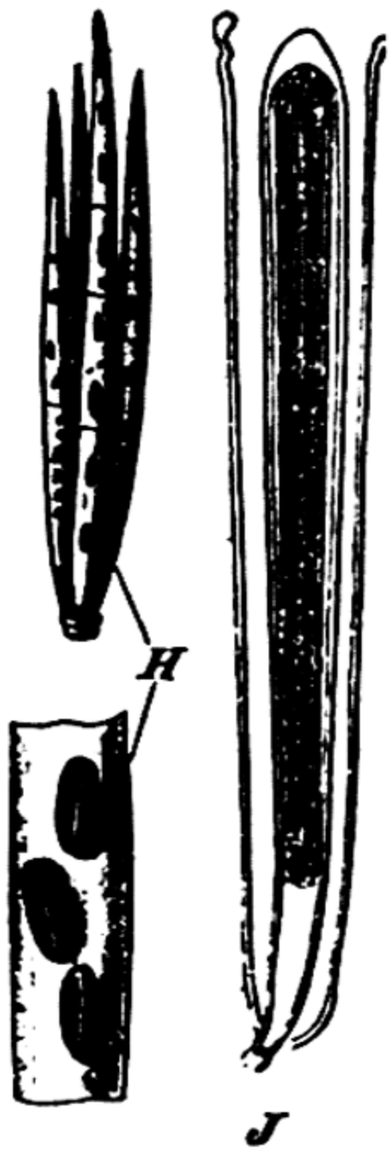


FIG. 114.—L. pinastri. *H*, habit sketch; *J*, ascus and paraphyses. After Rehm.

Several other species are parasitic upon various conifers, among them: **L. macrosporium** (Hart.) Rehm, on spruce leaves, in Europe and America; **L. nervisequum** (D. C.) Rehm, on fir leaves, a very destructive European species; the pycnidial stage is Septoria pini Fuckel; **L. juniperinum** (Fr.) d Not, on juniper leaves and twigs in Europe and America; **L. gilvum** Rost., on pines; **L. abietis** Rost., on spruce leaves; **L. laricinum** Duby, on larch. The last four species are European.

Dichænaceæ (p. 160)

This family contains the single genus Dichæna.

Dichæna Fries

Apothecia grouped in rounded spots; at first sunken, then erumpent, rounded or elongate, dark brown; asci irregularly pyriform, 4 to 8-spored; spores ellipsoidal, at first 1-celled, at maturity multicellular; paraphyses filiform. Some seven species are found upon various trees.



FIG. 115.—Hysterium macrosporum. After Hartig.

D. quercina Fr. causes rough black patches on bark of young oaks in Europe and America; **D. faginea** Fr., a similar effect on beech.

Hysteriaceæ (p. 160)

Ascocarps free, seated upon the substratum, elongate or linear, straight, curved or even branched, disk-form, boat-shaped or band-like, black; asci usually 8-spored; paraphyses filamentous, often forming an epithecium.

About fourteen genera and some two hundred fifty species, many but poorly known. Several genera contain plant pathogens, but they are not often of economic importance.



FIG. 116.—D. quercina. Ascus and paraphyses. After Rehm.

KEY TO GENERA OF Hysteriaceæ

Ascoma linear, flattened, broadly sessile
  Spores ellipsoid or spindle-shaped, many-celled
    Spores 1-celled, 16 in each ascus..... 1. **Cyclostomella.**
    Spores 2-celled, sometimes 4-celled, ellipsoid or elongate
Spores hyaline
  Asci 8-spored, spores 2 to 4-celled
    Paraphyses scarcely branched. . 2. **Aulographum.**
    Paraphyses forming an epithecium..... 3. **Glonium.**
  Asci many-spored, spores 2-celled. 4. **Hariotia.**
Spores colored, 2-celled; leaf infecting fungi
  Paraphyses present
    Ascoma seated on a cottony stroma. ..... 5. **Lembosia.**
    Ascoma radial, on a circular stroma
      Spores 2-celled, 8 in each ascus. ..... 6. **Parmularia.**
  Paraphyses absent, stroma irregularly circular. ..... 7. **Hysterostomella.**
Spores 4 to 8-celled, elongate or spindle-form
  Spores hyaline, spindle-form, 4-celled..... 8. **Hysteroglonium.**

Spores brown, elongate, 4 to 8-celled.	9. **Hysterium.**
Spores elongate, muriform.	10. **Hysterographium,** p. 164.
Ascoma boat or band-shaped, not sessile	
Spores spindle-formed, brown, many-celled	
Spores 4 to 8-celled; asci 8-spored.	11. **Mytilidium.**
Spores many-celled; asci 4-spored.	12. **Ostreion.**
Spores filamentose, hyaline or yellow	13. **Lophium.**
Ascoma stellate.	14. **Actidium.**

Hysterographium Corda

Asci clavate, 8-spored; spores muriform, dark colored when mature; paraphyses branched forming an epithecium. About seventy species.

H. fraxini (Pers.) de Not. occurs on Oleaceæ, particularly on



FIG. 117.—H. fraxini. Ascus and paraphyses. After Rehm.

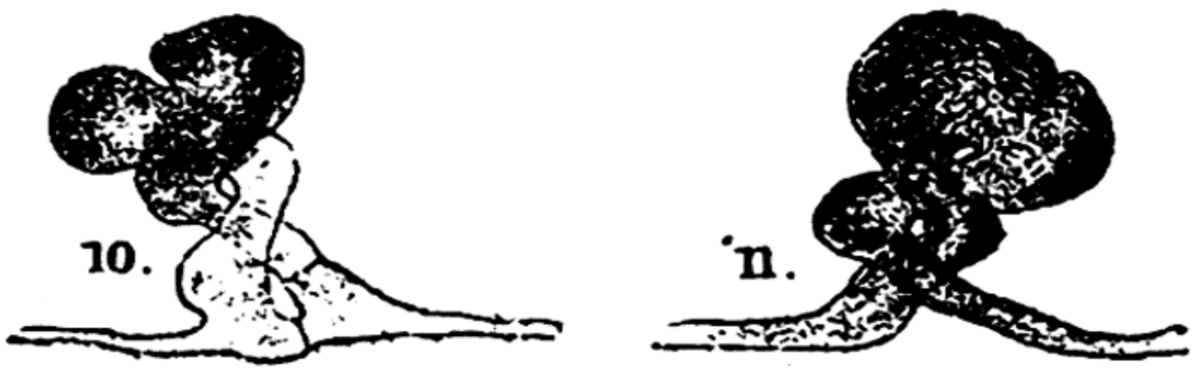


FIG. 118.—Gymnoascus, sexual organs. After Dale.

the ash, perhaps only as a saprophyte. It is found both in Europe and America.

Aspergillales (p. 124)

The Aspergillales are clearly distinguished from the other Ascomycetes by the possession of a closed ascocarp in which the asci are not collected in a hymenium but are irregularly scattered. The forms with the least developed peridium are evidently related

to the Endomycetaceæ; the forms with a more highly developed peridium, to the Pyrenomycetes, particularly to the Perisporiales. Conidial forms are usually present, indeed in many cases they preponderate almost to the entire exclusion of the ascigerous form which may be seen only under very exceptional conditions.

Sexual reproduction has been demonstrated in several families. In the Gymnoascaceæ (Dale [68] and Eidam [69]) there are usually two twisted branches (Fig. 118) which conjugate. These branches are multinucleate at the time of fusion. The ascogonium develops from this fertilization much as is described on pages 116–117. In the Aspergillaceæ similar sexual organs are formed but parthenogenesis or a much reduced form of fertilization is often met. In all, the species number two hundred fifty or more.

Key to Families of Aspergillales

Peridium made up of loose floccose hyphæ.	1. **Gymnoascaceæ.**
Peridium compact, closed	
Ascocarps mostly small, not subterranean	
Ascocarps mostly sessile without stroma; peridia remaining closed. .	2. **Aspergillaceæ,** p. 166.
Ascocarps mostly stalked; peridia opening at maturity by lobes, or irregularly	3. **Onygenaceæ.**
Ascocarps sessile, the spores issue in columnar masses from the goblet-shaped peridia.....	4. **Trichocomaceæ.**
Ascocarps sessile on a small stroma...	5. **Myriangiaceæ,** p. 170.
Ascocarps mostly enlarged, tuberous, subterranean.	
Peridium clearly distinct from the walls of the ascocarp; spore masses powdery at maturity.	6. **Elaphomycetaceæ.**
Peridium not clearly limited, continuous with the walls of the ascocarp; spore masses never powdery.....	7. **Terfeziaceæ.**

Of these the second and fifth families only contain pathogens. The Gymnoascaceæ of five genera and some fifteen species are found on manure, and other organic matter. The third and fourth

families are monogeneric; the third on hoofs, horn, etc.; the sixth is subterranean and the Terfeziaceæ more or less subterranean.

Aspergillaceæ (p. 165)

The ascocarp, in many forms but rarely seen, is a small spherical or tuber-shaped body, usually indehiscent, rarely opening by a pore. The spherical or pyriform asci bear from 2 to 8 spores which may be from 1 to many-celled. The ascocarp is in some genera provided with appendages which strongly resemble these of the Erysiphaceæ (Microascus). Conidia are produced in great abundance.

In Aspergillus and Penicillium fertilization is said by some observers to be accomplished by conjugation of a straight oögonium with a spirally coiled antheridium, this act resulting in an ascogenous hypha. Recent work of Dale [70] (see also Fraser and Chambers [71]) denies such fusion in one species of Aspergillus which she studied, though sexual organs were often present, and predicates a reduced form of sexuality consisting of fusion of the nuclei of the ascogonium with each other.

Key to Genera of Aspergillaceæ

Spores 1-celled
- Perithecium flask-shaped, beaked or papillate. . . . . 1. **Microascus.**
- Perithecium not beaked
  - Perithecium with hair-like appendages; peridium compact, mostly dark colored
    - Appendages straight hairs or forming a hairy felt. . . . . 2. **Cephalotheca.**
    - Appendages apically coiled hairs. . . . 3. **Magnusia.**
  - Perithecium unappendaged; peridium membranous or fleshy
    - Conidia borne directly on the mycelium
      - Chlamydospores borne in chains. . 4. **Thielavia,** p. 167.
      - Chlamydospores borne singly. . . . . 5. **Rostrella,** p. 168.

Conidia borne on distinct conidiophores	
Conidia borne singly; conidiophores branching at right angles	6. **Aphanoascus.**
Conidia borne in chains	
Conidiophores simple, aggregated into bundles	7. **Emericella.**
Conidiophores enlarged apically bearing numerous sterigmata	
Sterigmata simple	8. **Aspergillus,** p. 168.
Sterigmata branched	9. **Sterigmatocystis.**
Conidiophores, sympodially branched	10. **Eurotiopsis.**
Conidiophores bushy branched	
Conidiophores single, perithecia sessile	11. **Penicillium,** p. 169.
Conidiophores in bundles, apical cells swollen, perithecia stalked	12. **Penicilliopsis.**
Spores 2-celled; peridium at maturity stellate	13. **Testudina.**

Of the thirteen genera and some one hundred to two hundred species only four of the genera are of interest here. The others occur on rotting leaves, manure, etc.

Thielavia Zopf [72–74] (p. 166)

T. basicola (B. and Br.) Zopf.

This, the one species of the genus, is on the boundary between the Aspergillales and the Perisporiales and is classed by some with the one, by some with the other order.

The ascocarps, which are the form less commonly seen, are round, brown, completely closed and have no appendages. The asexual spores are of two kinds. First: hyaline conidia produced endogenously within "pistol-formed" conidiophores from the ends of which they are expelled. Second: short cylindrical conidia or chlamydospores with a thick brown wall; borne in series of

three to six on the ends of hyaline branches, Fig. 119. These conidia fall apart as they age.

The hyaline conidia preponderate in early disease, giving the surface of the root a mildewed appearance; the dark conidia preponderate later, covering the root with a black coating. Finally, after the host is dead, the ascocarps appear.

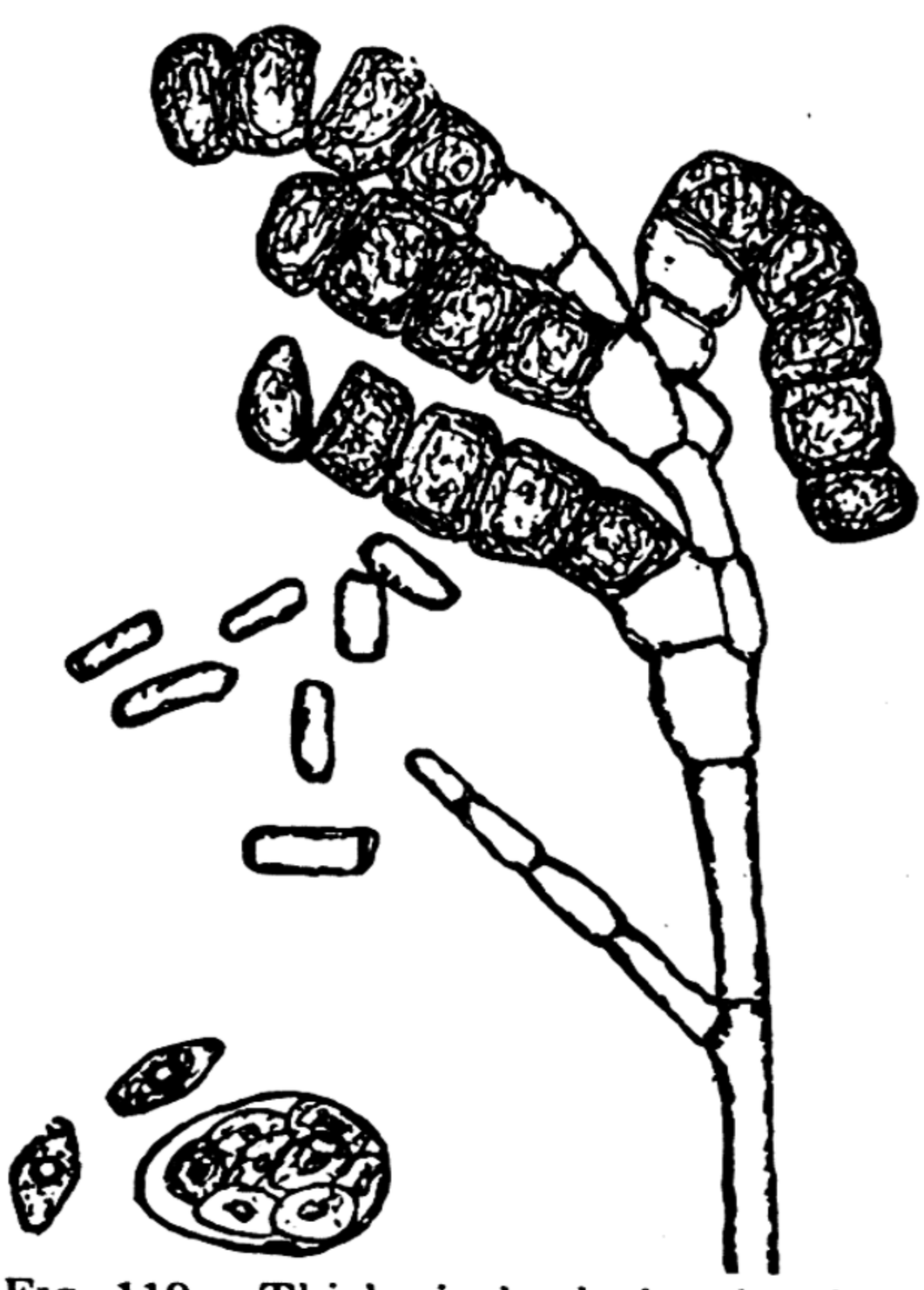


FIG. 119.—Thielavia basicola, showing two conidial forms and ascus and ascospores. After Van Hook and Zopf.

The delicate hyaline mycelium wanders through the affected root disorganizing its tissue. The superficial mycelium is lightly tinted.

Perithecia 80–100 μ; asci ovate, 8-spored; spores lenticular, vacuolate, 1-celled, chocolate-colored, 8–12 x 4–5 μ; chlamydospores in chains, at maturity separating, short-cylindric, about 5–8 x 12 μ; the entire group 25–65 μ long; conidia hyaline about 10–20 x 4–5 μ.

In Europe and Eastern North America on Aralia quinquefolia, Begonia rubra, Begonia sp., Catalpa speciosa, Cyclamen sp., Gossypium herbaceum, Linaria canadensis, Lupinus angustifolius, L. albus, L. luteus, L. thermis, Nasturtium armoracea, Nemophila auriculata, Nicotiana tabacum, N. rustica, Onobrychis cristagalli, Oxalis stricta, Phaseolus vulgaris, P. multiflorus, Pisum sativum, Senecio elegans, Trifolium repens, Trigonella cœrulea, Vigna sinensis and Viola odorata.

Rostrella coffeæ Zimm. is described as the cause of canker of coffee in Java.[75]

Aspergillus Micheli (p. 167)

The ascocarps are small, spherical, indehiscent, smooth bodies which at maturity are entirely filled with 8-spored asci; spores

1-celled. The conidiophores, which serve better to characterize the genus, are swollen at the end, and bear numerous sterigmata (Fig. 120) on which the spores are borne basipetally in chains. Sclerotia are sometimes formed.

The members of the genus are all saprophytes but some of them



A

FIG. 120. — Aspergillus, conidiophore. After King.

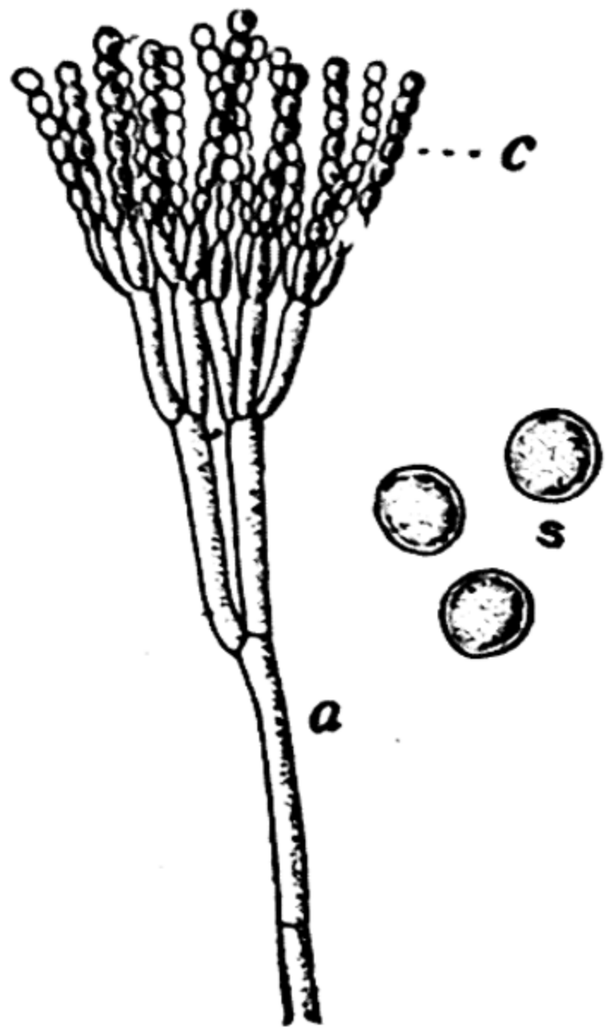


FIG. 121. — Penicillium, showing a conidiophore; *a*, producing chains of conidia, *c*; *s*, three spores more highly magnified. After Longyear.

cause injury to fruit in the tropics; for example, **A. ficuum,** Reich. on figs; **A. phœnicis** Pat. & Del. on dates.

Penicillium Link [76] (p. 167)

The ascocarp is much as in the last genus, with the asci 4 to 8-spored. It may develop directly from the mycelium or with the intervention of a sclerotial stage. The characteristic conidiophore serves to distinguish the genus by its mode of branching. Fig. 121. Instead of being apically swollen as in the preceding genus it branches repeatedly, the branches bearing terminal sterigmata and giving the conidiophore the appearance of a brush; hence the name. For species see page 573.

Myriangiaceæ (p. 165)

Perithecia numerous upon or in a stroma; asci in a pseudoparenchymatous substance within the perithecium; spores muriform.

Key to Genera of Myriangiaceæ

Stroma valsoid, perithecia superficial.... 1. **Myriangium.**
Stroma effused, perithecia immersed.... 2. **Myriangiella, p. 170.**

Myrangiella orbicularis Zimm. parasitizes coffee in Java.[300]

Pyrenomycetes [52]

The four following orders are usually grouped together as the Pyrenomycetes; separated from the preceding forms by their closed ascocarp with the asci arranged in a hymenium. They constitute a vast assemblage of more than ten thousand species, the large majority saprophytic and unimportant except in the general economy as scavengers.

Perisporiales (p. 124)

The present order is characterized by its almost universal parasitic habit, the evident mycelium and the globoid perithecia without ostioles, or in one family flattened, ostiolate perithecia. The mycelium is superficial upon the host and frequently quite conspicuous.

Key to Families of Perisporiales

Perithecia mostly spherical, imperforate
  Mycelium white; perithecia with appendages..... 1. **Erysiphaceæ, p. 171.**
  External mycelium dark colored or wanting, perithecia without true appendages, but sometimes surrounded by appendage-like hyphae..... 2. **Perisporiaceæ, p. 189.**
Perithecia flattened, shield-shaped, ostiolate..... 3. **Microthyriaceæ, p. 195.**

Erysiphaceæ (p. 170) [46, 52, 77, 78]

This family on account of its abundance everywhere, its simplicity of structure, and its possession of typical ascigerous and conidial stages forms a favorite type for introductory study of the Ascomycetes. Its members are easy of recognition, forming a coating of white conidia, conidiophores and mycelium upon the surface of its hosts and giving them an appearance much as though they had been lightly dusted with flour. Later in the season the white patches are more or less liberally sprinkled with the black perithecia leading to the common name powdery mildew. An important list of the economic forms and their hosts has been published by Halsted.[77]

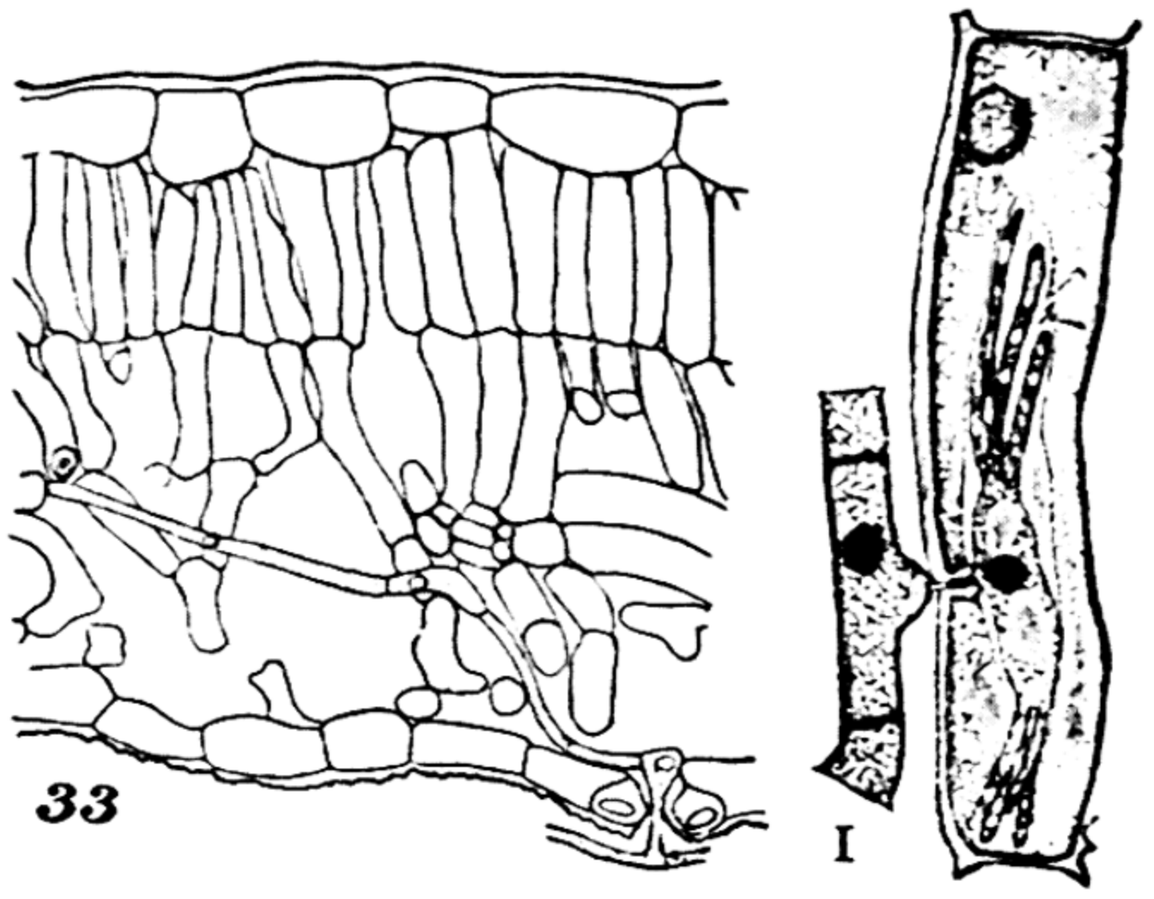


FIG. 122.—I, E. graminis, showing branching haustoria. 33, Phyllactinia, intercellular hyphæ. After Smith.

The mycelium except in Phyllactinia is entirely superficial. It is usually quite hyaline and is branched, septate and its cells uninucleate. It fastens to the host and penetrates its epidermal cells by uninucleate haustoria which by their various lobings aid in specific characterization. Figs. 122, 123.

Haustoria may be grouped in three general classes; (1) those arising directly from the lower surface of the mycelium; (2) those arising at the side of the mycelium as small semicircular processes; (3) arising from more or less deeply-lobed lateral swellings of the mycelium. The relation of the haustoria to the host cells has been extensively studied by Smith.[79]

The conidia arise in basipetal succession on simple scattered conidiophores (Fig. 129); are hyaline, oval or barrel-shaped, smooth, 1-celled. Neger has shown that they vary greatly in size with nutrition conditions.[80]

Conidia germinate readily at once in dry air, better in humid air, producing from one to three germ tubes. Haustoria are

formed at once and the mycelium develops to a more or less circular colony, producing new conidia in a few days. Artificial inoculations on susceptible plants, using conidia, usually result within two to five days in typical mildew spots.

Neger,[80] who studied the germination of conidia extensively has shown that light hastens the growth of the germ tubes, which in many cases are negatively phototropic. Contact stimulus leads to the growth of appressoria.

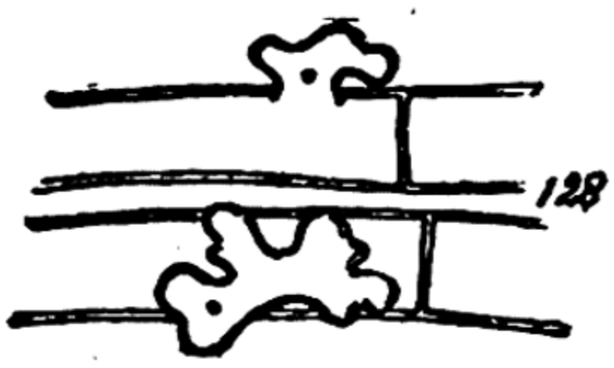


FIG. 123. — Erysiphe, showing lobed haustoria. After Salmon.

The perithecia are subspherical, often somewhat flattened, white to yellow when young, dark to black and reticulated when mature; are without ostiole but are provided with appendages of various types, Figs. 130, 133–136, which give main characters to mark the genera. The appendages serve by hygroscopic movements to aid in the distribution of the fungus.[81] The ascospores become free after dissolution of the perithecium by weathering. The asci are either solitary or quite numerous within the perithecium and bear two to eight hyaline spores each.

The conidia are short-lived summer spores. The perithecia mature more slowly and constitute the hibernating condition. In some instances the ascus-form is unknown; the fungus is then classified solely by its conidial stage and falls under the form genus Oidium (see p. 569.)



FIG. 124.—Ascogonium-tube with five nuclei. After Harper.

In Sphærotheca[82] an antheridial and an oögonidial branch, each uninucleate, are developed, and cut off by septa. The oögonium enlarges; the antheridium lengthens, its nucleus divides, and a septum is run in separating the stalk cell from the antheridium. The sperm nucleus enters the oögonium and fuses with the oögonial nucleus. Simultaneous with fertilization occurs, from the stalk cell of the oögonium, the development of a sterile system of enveloping threads which surround and protect the fertilized oögonium and eventually mature into the sporocarp. The fertilized oögonium divides several times transversely producing a series of cells, one of which is binucleate.

This binucleate cell after fusion of its nuclei develops into the one ascus characteristic of the genus. The ascus nucleus by division gives rise to the spore nuclei and the spores are cut out of the periplasm by reflexion of the astral rays.

In Erysiphe [83] the oögonium and antheridium arise in a very similar way, the oögonium being somewhat curved. Fertilization is also similar consisting of the union of two gametic nuclei. After fertilization the oöspore nucleus divides and the oögonium develops into a short bent tube, which contains from five to eight nuclei. Septa now appear cutting off cells, some uninucleate, some with two or more nuclei. The ascogenous hyphæ develop a knot and soon divide into two or three cells each and give rise to the asci which are in the beginning binucleate.

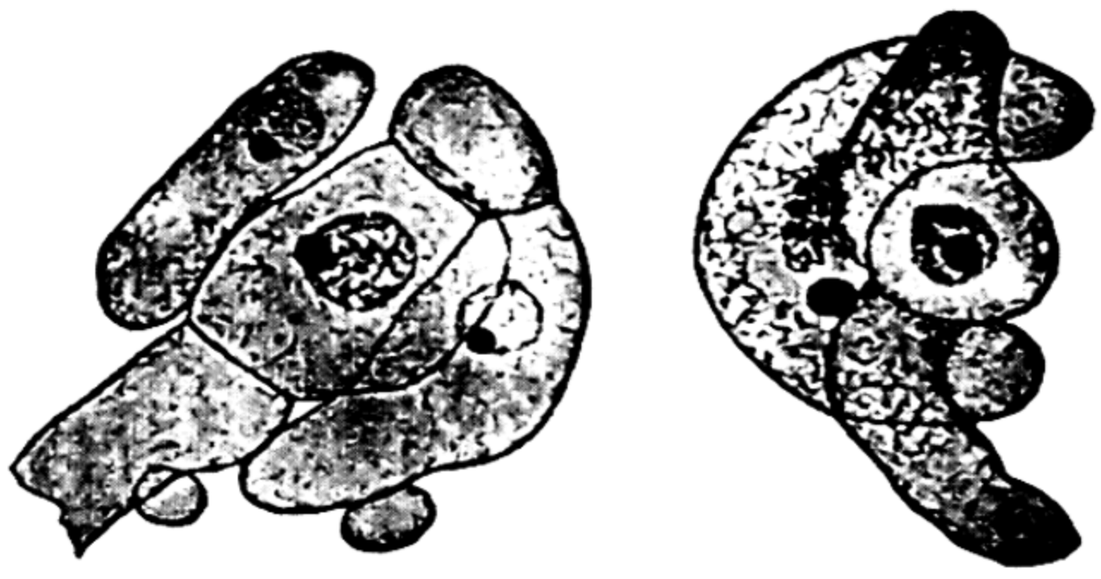


FIG. 125.—Phyllactinia, male and female branches; uninucleate oögonium and antheridium. After Harper.

In Phyllactinia [84] the oögonium, antheridium and fertilizations are as in Erysiphe, though the oögonium may be quite curved so as to make almost a complete turn around the antheridium. Fig. 125.

After fertilization the antheridium degenerates and enveloping protective hyphæ arise both from the oögonium and the antheridium stalk cells. The oögonium becomes three to five nucleate and develops to a row of cells of which the penultinate cell has more than one nucleus. The ascigerous hyphæ arise from this binucleate cell, perhaps also from other cells of the series, become septate and form the asci either terminally, laterally or intercalary. The young ascus is binucleate, fusion follows and the spores develop as in the preceding genera.

The family contains, according to Salmon,[46] forty-nine species and eleven varieties, according to Saccardo more than one hundred species. These are parasitic on some one thousand five hundred hosts, some of them upon economic plants and of serious harmfulness.

The matter of delimiting species and even genera is often difficult, owing to intergrading forms. This question is complicated

still further by biologic specialization such that forms which are indistinguishable under the microscope show in inoculation tests different abilities regarding host infection. Thus Neger,[80] Salmon,[85,86] Reed,[87] and others have shown that spores borne on a particular host are capable of infecting only that host or in other cases only nearly related species of the same host genus. Forms which can pass from one genus to another are less common. Forms morphologically distinct are regarded as separate species. Differentiations within such species, regarding the species of host plant which they parasitize, give rise to "biologic species" or "biologic varieties."

Reed [87] writes of these biologic forms thus:

"So far as investigated, Erysiphe cichoracearum, is the only one with doubtful exceptions, . . . shown to be capable of infecting plants belonging to more than one genus."

"There are other cases where the mildew is limited closely to plants of a single genus," and "Several cases are recorded where the mildew from one species will not infect other species of the same genus. Most of these claims, however, rest on insufficient data."

Some morphological species show a very wide range of hosts; one species, Phyllactinia corylea is known on forty-eight genera in twenty-seven families, others are limited to single genera or to single species of host plant. Two, three, and even five species are recorded for some species of host.

Geographically the Erysiphaceæ are widely distributed, practically of world distribution, but they are more abundant in the temperate zones than elsewhere.

A pycnidium-bearing parasite, Cicinnobolus, p. 494, is quite frequently found on the mycelium and conidiophores of the Erysiphaceæ.

Owing to the extreme variability of the perithecial characters and the almost promiscuity of host selection this family presents a most difficult problem to the taxonomist who must either segregate or "lump" species. No middle ground seems open at present.

Key to Subfamilies and Genera of Erysiphaceæ

Mycelium wholly external to the tissues of the host plant, usually sending haustoria into the epidermal cells only, perithecial appendages various, more or less flaccid — I. **Erysipheæ.**

Perithecial appendages indeterminate, similar to the mycelium, simple or irregularly branched	
Perithecia containing a single ascus...	1. **Sphærotheca,** p. 175.
Perithecia containing several asci.....	2. **Erysiphe,** p. 177.
Perithecial appendages determinate	
Appendages hooked or coiled at the apex.....	3. **Uncinula,** p. 180.
Appendages dichotomous at the apex	
Perithecia containing a single ascus.	4. **Podosphæra,** p. 182.
Perithecia containing several asci...	5. **Microsphæra,** p. 185.
Mycelium with special intercellular haustoria-bearing branches which enter the host by the stomata; perithecial appendages rigid, with a bulbous base...	II. **Phyllactinieæ.**
A single genus.....	6. **Phyllactinia,** p. 187.

Sphærotheca, Léveillé

Perithecia subglobose; appendages floccose, brown or hyaline, spreading horizontally and often interwoven with the mycelium, simple or vaguely branched, frequently obsolete; ascus single, 8-spored. Five species, according to Salmon;[46] Engler and Prantl[7] give fourteen.

S. humuli (D. C.) Burr.[88-89]

Amphigenous; mycelium usually evanescent; perithecia usually somewhat gregarious, but varying from scattered to cespitose, 58–120 μ in diameter; cells small, averaging 15 μ; appendages few or numerous, usually long, often exceeding nine times the diameter of the perithecium, more or less straight, septate, dark brown throughout: variations are, short, flexuose, pearly-brown, white or even obsolete. Ascus broadly-elliptic to subglobose, rarely abruptly stalked, 45–90 x 50–72 μ; spores 20–25 x 12–18 μ, rarely larger, averaging 22 x 15 μ.

Conidia (=Oidium fragariæ) ovate, white, membrane smooth.

Salmon[90] has shown that subjecting the conidia of this variety to low temperature, 0° two hours, increases their germinating power. Sowing ascospores from the hop, on hop, Potentilla and Spirea he secured infection only on the hop.[91] Conidia from hop infected hop but not Spirea.

The species is cosmopolitan and among its numerous hosts are the economic genera Dipsacus, Fragaria, Humulus, Phlox, Pyrus, Rosa, Ribes, Rubus, Scabiosa, Spirea and Viola.

It is a common rose mildew of America and England and is also especially destructive on the strawberry.

S. humili var. **fuliginea.** (Schl.) Sal.

Perithecia usually smaller than in the last, sometimes only 50 μ in diameter, wall usually harder and more brittle, cells larger, irregularly shaped, averaging 25 μ; appendages usually short, pale brown; spores 20–25 x 12–15 μ.

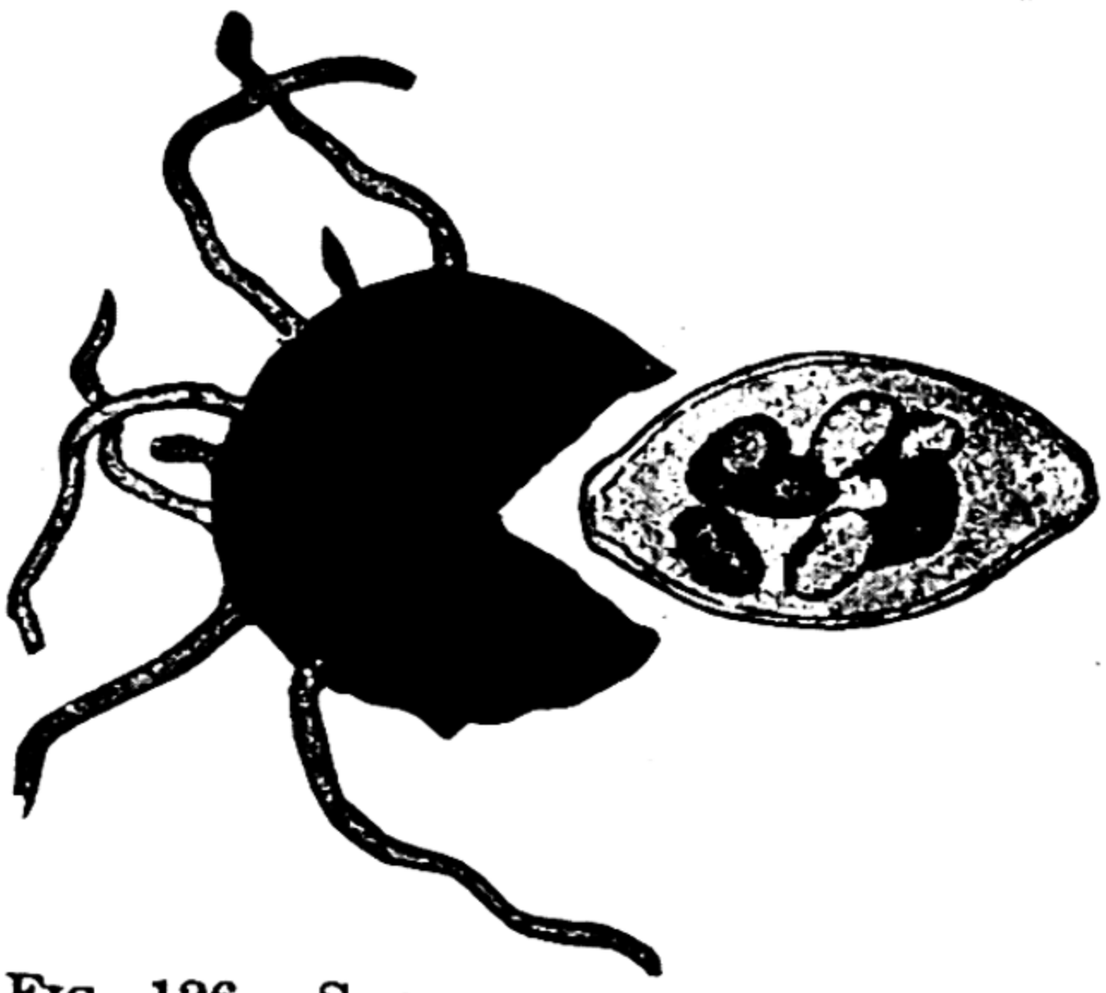


FIG. 126.—S. mors-uvæ, a perithecium discharging its single ascus which contains eight spores. After Longyear.

Throughout Europe, Asia and North America.

It is recorded on Arnica, Calendula, Coreopsis, Fragaria, Gaillardia, Impatiens, Phlox, Scabiosa, Taraxacum, Verbena, Viola, and several other non-economic genera.

S. pannosa (Wallr.) Lév.[92–93]

Mycelium persistent, forming dense satiny patches on the stem, calyx, petiole, and rarely on leaves, at first shiny white, then becoming gray, buff or rarely brown; perithecia more or less (usually completely) immersed in the persistent mycelium, globose to pyriform, 85–120 μ in diameter, usually about 100 μ; cells obscure, about 10 μ wide; appendages few, often obsolete, very short, tortuous, pale brown, septate; ascus broadly-oblong to globose, 88–115 μ, averaging 100 x 60–75 μ; spores 20–27 x 12–15 μ.

Conidia (=Oidium leucoconium) ovoid, 20–30 x 13–16 μ, hyaline; conidiophores short.

Hosts: peach and rose; cosmopolitan.

The conidia are very common on the rose, but the perithecia are rare. What often passes for this species on roses in America is in reality S. humili.[46]

S. mors-uvæ (Schw.) B. & C.[94–95]

The mycelium at first white, is exceptional among the Erysipheæ

in that it later becomes quite brown. It is found in closely felted patches on stems and fruit. Perithecia begin to form in June.

Amphigenous; mycelium persistent, at maturity forming dense pannose patches of brownish hyphæ; perithecia gregarious, more or less immersed in the persistent mycelium, subglobose, 76–110 μ in diameter; cells large, at first well defined, then becoming obscure, 10–25 μ wide; appendages usually few or even obsolete, pale-brown, short, rarely longer, up to five times the diameter of the perithecium, tortuous; ascus elliptic-oblong to subglobose, 70–92, rarely 100 x 50–62 μ; spores 20–25 x 12–15 μ.

On wild and cultivated species of Ribes in America; recently introduced into Europe where it is very destructive.

S. lanestris Hark. occurs on various species of oaks in the United States.

Erysiphe Hedwig (p. 175)

Perithecia globose, or slightly depressed, rarely concave; appendages floccose, simple or irregularly branched, sometimes obsolete, usually more or less similar to the mycelium and interwoven with it; asci several, 2 to 8-spored.

Salmon [46] recognizes eight species; Engler and Prantl,[7] twenty.

E. polygoni D. C.[97]

Amphigenous; mycelium very variable, persistent, thin, effused and arachnoid, rarely thick, or more often evanescent; perithecia gregarious or scattered, usually rather small, averaging 90 μ, but ranging from 65 to 180 μ; cells usually distinct, 10–15 μ wide; appendages very variable in number and length, few or many, distinct or more or less interwoven with the mycelium, brown or colorless; asci 2–8 or rarely as many as 22, variable in shape and size, usually small and ovate, with or without a short stalk, 46–72 x 30–45 μ; spores 3–8 rarely 2, 19–25 x 9–14 μ.



FIG. 127.—E. polygoni, the asci. After Salmon.

Conidiophores (=Oidium balsamii) medium; conidia ovate, hyaline.

One of the commonest species, especially destructive to the pea and turnip. It was studied by Salmon on one hundred ninety host

species belonging to eighty-nine genera; one hundred forty-six more hosts, some doubtful, are reported. Among the economic host genera are Adonis, Alyssum, Anemone, Aquilegia, Brassica, Calendula, Catalpa, Clematis, Cucumis (?), Cucurbita (?), Dahlia, Daucus, Delphinium, Diervilla, Dipsacus, Fagopyrum, Lupinus, Lycopersicum, Medicago, Pæonia, Phaseolus, Pisum, Tragopogon, Trifolium, Verbena, Vicia, Scabiosa, Symphytum, Valeriana.

This is the most variable species of this genus varying widely in its every character. It includes several species which have by some been set aside as distinct, e. g., E. martii, E. umbelliferarum and E. liriodendri.



FIG. 128.—E. cichoracearum, asci and spores. After Salmon.

Salmon [98] found that the conidia of this form grown on Trifolium pratense were unable to infect other species of Trifolium.

E. cichoracearum D. C.[96]

Amphigenous; mycelium usually evanescent, rarely persistent, white or sometimes pink; perithecia gregarious or scattered, 80–140 or rarely 180 μ; cells variable, often very distinct, 10–20 μ; appendages variable in number and size, some shade of brown; asci usually numerous, about 10–15, but varying from 4 to 36, variable in size and shape, narrowly ovate or subcylindric to broadly-ovate, more or less stalked, 58–90 x 30–35 μ; spores 2, rarely 3, 20–28 x 12–20 μ.

Conidiophores (=Oidium ambrosiæ Thüm), short; conidia minute, elliptic, white, 4–5 x 7–5.3 μ. The species is quite variable sometimes closely approaching E. polygoni.

Cosmopolitan. The hosts are very numerous, among them being: Borago, Calendula, Centaurea, Cichorium, Clematis, Cucurbita, Dahlia, Helianthus, Humulus, Mentha, Nicotiana, Phlox, Tragopogon, Valeriana, Verbena, Symphytum. It is of especial import on composites and cucurbits.

Reed [99] has made very extensive culture studies of this species

and concludes that the same form of "Erysiphe cichoracearum D. C., occurs on at least eleven species of the cucurbits, belonging to seven genera, infection occurring in these cases in fifty per cent or more of the trials. Six other species were also infected, but in a smaller percentage of cases. . . . It is also plain that the biologic form of Erysiphe cichoracearum, occurring on so many cucurbits is not entirely confined to the species of this one family. Out of fifty-four leaves of Plantago rugelii, a species belonging to the Plantaginaceæ, which were inoculated, ten became infected. . . . Furthermore out of ten leaves of squash seedlings, inoculated with conidia from plantain, six became infected . . . and the sunflower, Helianthus annuus, was infected in thirty-five per cent of the trials in which conidia from the squash were sown on leaves of seedlings. . . . The cucurbit mildew could not be transferred to asters and goldenrods nor was the mildew occurring on these in nature able to infect the squash. Neither the aster mildew nor the cucurbit mildew proved able to infect a goldenrod, Solidago cæsia. Nor was the mildew on this host able to infect asters or squashes."

E. taurica Lév. is found in Europe, North Africa and Asia on Capparis, Cicer, Clematis and various other hosts.

E. graminis D. C.

Usually epiphyllous, rarely amphigenous; mycelium more or less persistent, forming scattered patches, at first white, then brown or gray; perithecia large, 135–280 μ, usually about 200 μ, scattered or gregarious, cells obscure; appendages rudimentary, few or numerous, very short, pale brown; asci numerous, 9–30, cylindric to ovate-oblong, more or less long-pedicellate, 70–108 x 25–40 μ; spores 8, rarely 4, 20–23 x 10–13 μ, seldom produced on the living host plant.

Conidial form (=Oidium monilioides) with a grayish cast; conidiophores medium tall; conidia ovoid, white or sordid, 25–30 x 8–10 μ.

It is found on a large number of species of the Gramineæ in-

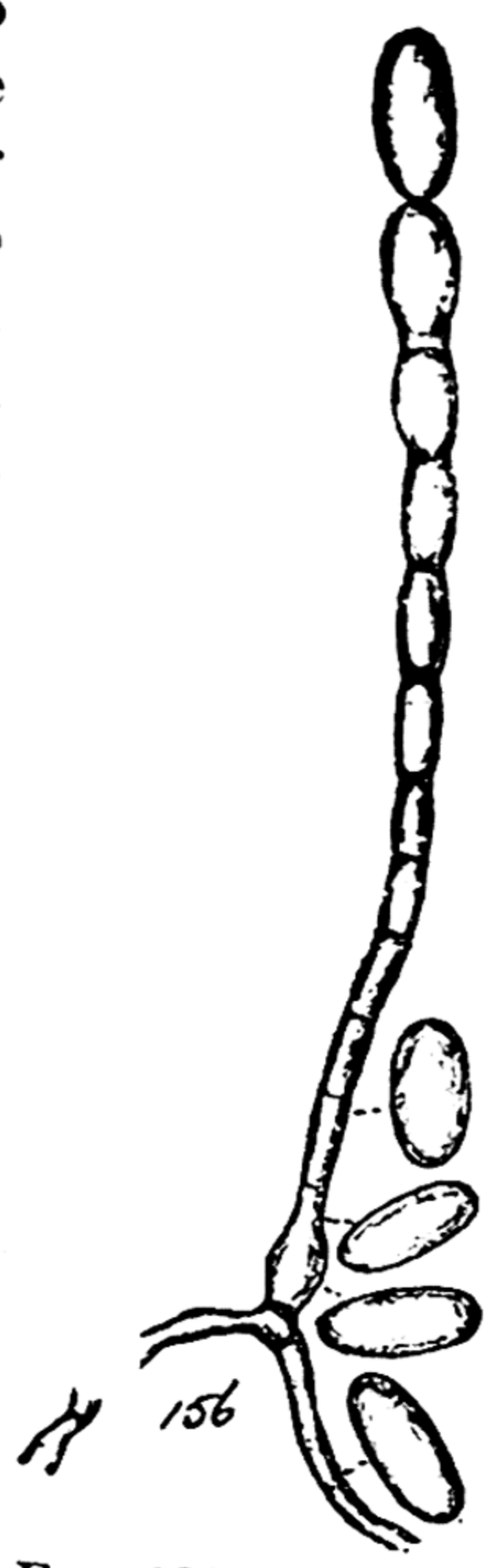


FIG. 129.—E. graminis, conidial stage. After Salmon.

cluding species of Avena, Festuca, Hordeum, Phleum, Poa, Saccharum, Secale, and Triticum.

The asci are peculiar in that they usually contain undifferentiated granular protoplasm, not spores, though in some cases the spores, normally 8, are present. Wolff [100] found that after a few days in water the undifferentiated ascoplasm developed spores which proceeded to normal germination.

This species on grasses shows no morphological differences, yet inoculation tests have revealed in it numerous biologic varieties. Reed [87] summarizes the results of his own work together with that of Marchal [101] and Salmon [102] as follows:

"So far as tested, all species of Avena are susceptible to the oat mildew. All species of Triticum are likewise susceptible to the wheat mildew. We find, however, that certain varieties of Triticum dicoccum are practically immune to the wheat mildew. Other varieties of this same species are entirely susceptible. Some species of Hordeum are immune to the barley mildew, and the same seems to be true of certain species of Secale with reference to the rye mildew.

"To these general statements there are two possible exceptions. Marchal states that the oat mildew will infect Arrhenatherum elatius. Salmon, however, obtained a negative result with the oat mildew on this grass. The evidence is not conclusive either way. The other exception is that, according to Salmon, conidia from wheat can infect Hordeum silvaticum.

"It would seem then that under normal conditions there are well-defined forms of Erysiphe graminis occurring respectively on the species of each of the four cereals."

It is thought that some hosts may act as bridging species and enable the parasite to pass from one host to another to which it could not pass directly.

Uncinula Léveillé (p. 175)

Perithecia globose to globose-depressed; appendages simple or rarely once or twice dichotomously forked, uncinate at the apex, usually colorless, rarely dark brown at base or throughout; asci several, 2 to 8-spored.

There are eighteen or twenty species.

U. necator (Schw.) Burr.[103, 104, 105]

Amphigenous; mycelium subpersistent; perithecia usually epiphyllous, occasionally hypophyllous or on the inflorescence, more or less scattered, 70–128 μ; cells distinct, rather irregular in shape, 10–20 μ; appendages very variable in number and length, 7–32, rarely up to 40, 1 to 4-times the diameter of the perithecium, septate, thin walled, light or dark amber-brown basally, rarely branched, asci 4–6 rarely up to 9, broadly-ovate or ovate-oblong to subglobose, with or without a short stalk, 50–60 x 30–40 μ; spores 4–7, 18–25 x 10–12 μ.

Conidial form (=Oidium tuckeri), conidiophores short; conidia elliptic, oblong, or obtusely rounded, 2 to 3-catenulate, hyaline, 25–30 x 15–17 μ.

Hosts Vitis, Ampelopsis and Actinidia. One of the worst pests of the family.

The mycelium is thin walled and sparingly septate. The haustoria arise from lobed lateral swellings of the hyphæ, penetrate the epidermis with a filamentous projection and swell within the host cell to a bladder-like body. The parasitized cells and later the neighboring ones turn brown and die.

The conidia germinate readily in moist air or in water, sending forth from one to several germ tubes.

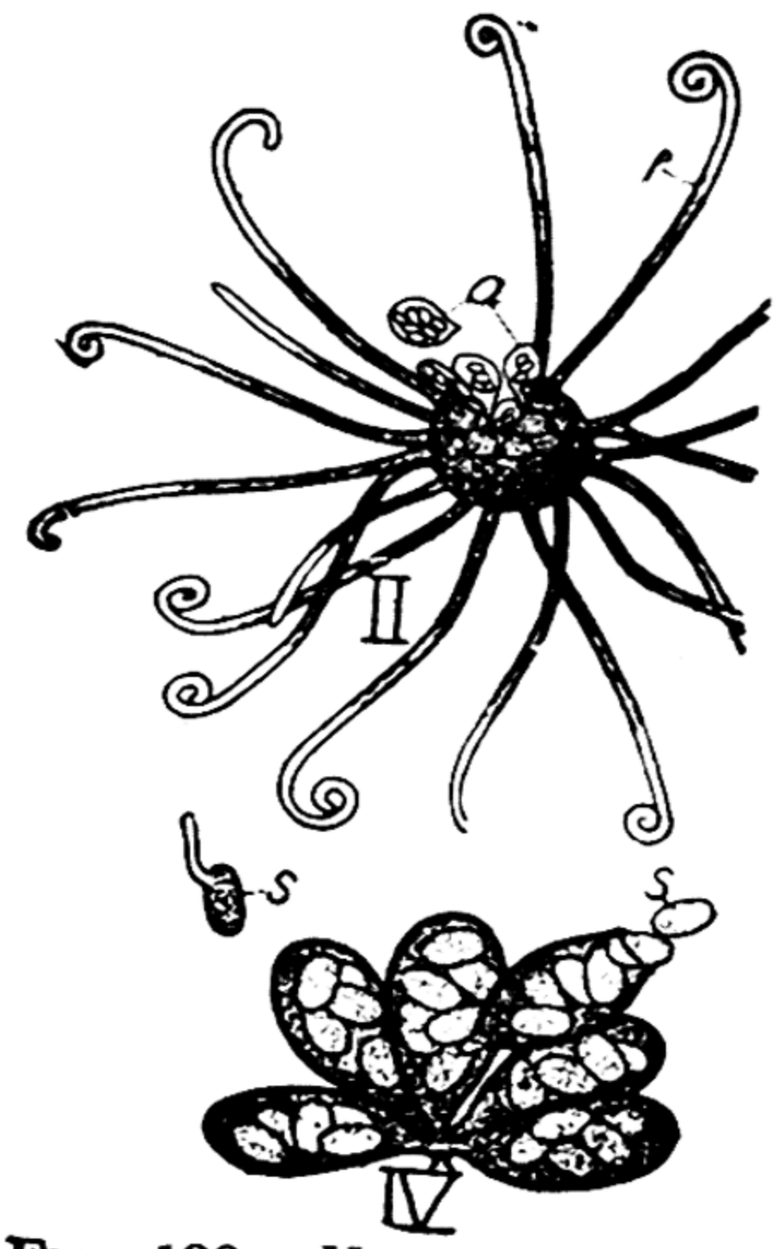
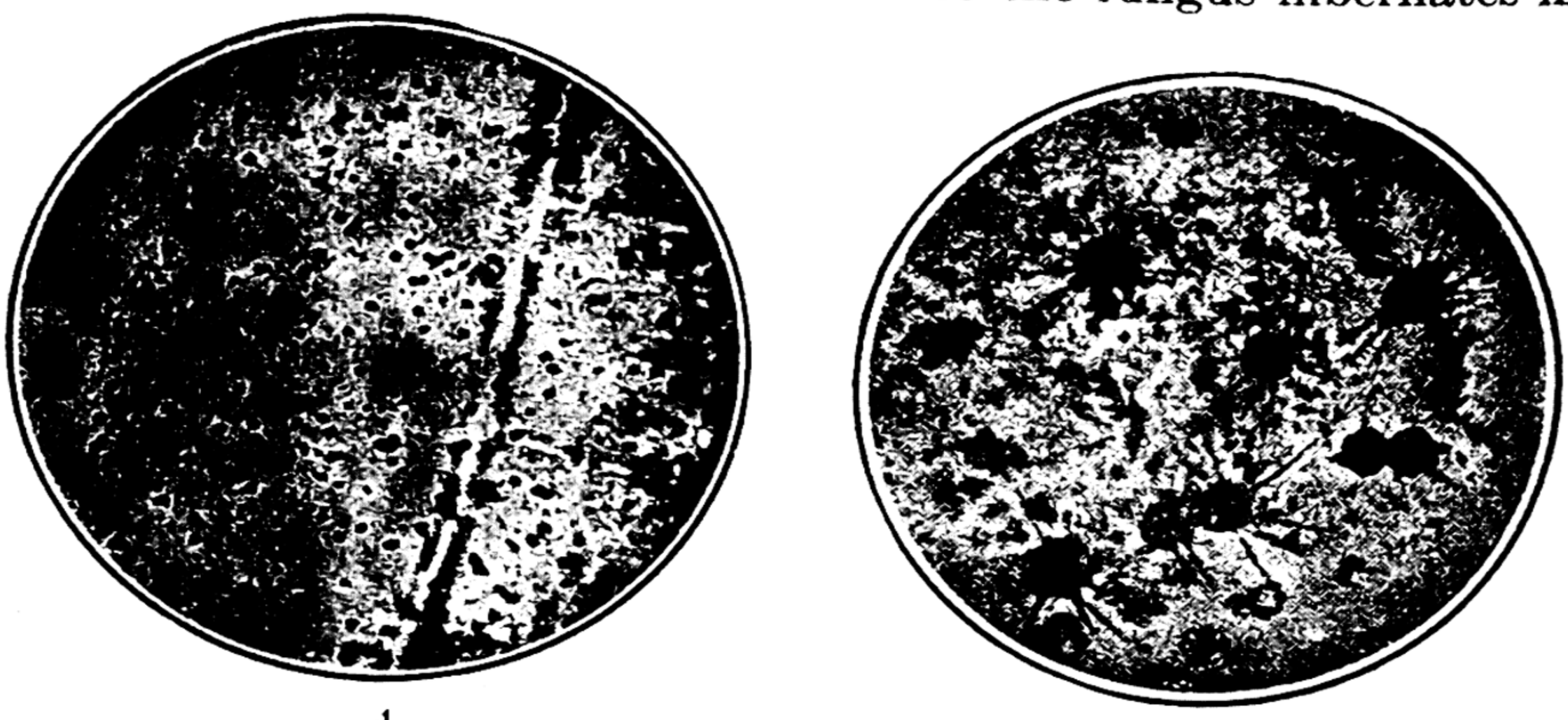


FIG. 130.—U. necator. II. Perithecium showing *f*, appendages, and *a*, asci. IV. Group of asci removed from perithecium emitting *s*, ascospores. After Viali.

The perithecia are found well developed as early as June or July in the United States and are rather evenly scattered over the affected surfaces. Bioletti [105] says that a period of warm moist weather which favors luxuriant mycelial growth, followed by sudden lowering of temperature to about 50° F., favors their most rapid formation. They are at first hyaline, later brown. After their form and walls become definite, usually during winter, the appendages develop as outgrowths from the outer walls. During winter the appendages break off. Galloway [104] failed to secure germination of ascospores earlier than February or March, but

perithecia which had been exposed to the weather until spring and were then placed in a hanging drop culture afforded spores, some of which grew though many of them burst as they emerged from the perithecium. Ascospores are known to have remained viable for at least eighteen months.[106] No successful infections were made from ascospores.

Though perithecia are frequently found in America they were not found in Europe until 1892 [107] and are now found there but rarely. It appears that in their absence the fungus hibernates in



A *B*

FIG. 131.—U. necator. Photomicrographs of perithecia on surface of leaf. *A*, Magnified 8 times. *B*, Magnified 35 times. After Bioletti.

specially resistant cells of the mycelium which develop within knotty swellings near the haustoria.[330]

U. salicis (D. C.) Wint. on willow and poplar in Europe, Asia, and America, **U. aceris** (D. C.) Sacc. and **U. circinata** C. &. P. on maple are common species. **U. flexuosa** Pk. occurs on Æsculus. and elm, **U. clandestina** (Biv.) Schr. on elm, **U. prunastri** (D. C.) Sacc. on species of Prunus, especially P. spinosa in Europe. **U. mori** Miy. is on Morus in Japan.[301] Several other species of small importance affect numerous hosts.

Podosphæra Kunze (p. 175)

Perithecia globose or globose-depressed; ascus solitary, subglobose, 8-spored; appendages equatorial or apical, dark-brown or colorless, dichotomously branched at the apex, branches simple

and straight or swollen and knob-shaped; appendages rarely of two kinds, one set apical, brown rigid, unbranched or rarely 1 to 2-times dichotomous at the apex, the other set basal, short, flexuous, frequently obsolete.

Salmon [46] recognizes four species; Engler and Prantl [7] seven.

P. oxyacanthæ (D. C.) De Bary [108, 109]

Amphigenous; mycelium variable, persistent in thin patches or evanescent; perithecia scattered or more or less gregarious, subglobose, 64–90 μ; cells 10–18 μ; appendages spreading more

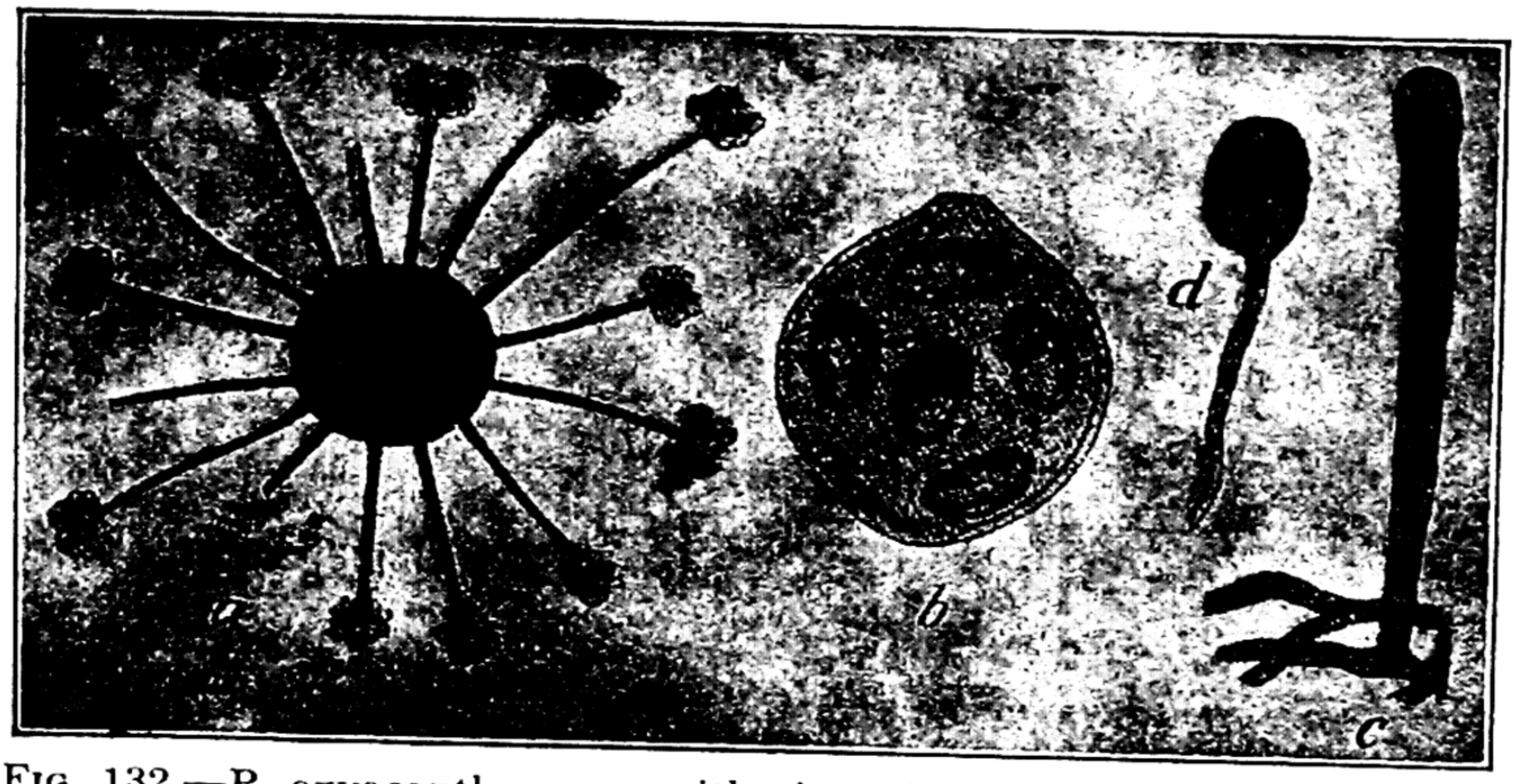


FIG. 132.—P. oxyacanthæ. *a*, perithecium showing the appendages with tips; *b*, the one large ascus containing eight spores; *c*, the summer spore-form; *d*, a spore germinating in water. After Longyear.

or less, equatorial, variable in number and length, from 4–30 in number and from ½–6 or even 10-times the diameter of the perithecium, usually unequal in length, dark brown for more than half their length from the base, apex 2 to 4-times dichotomously branched, branches usually short and equal, ultimate branches rounded, swollen, and more or less knob-shaped, Fig. 133; ascus broadly obovate, or subglobose, 58–90 x 45–75 μ; spores 8, rarely 6, 18–30 x 10–17 μ.

Conidia (=Oidium cratægi).

Salmon finds the species very variable but cannot set aside as separate species P. tridactyla and P. myrtillina as is done by some authors. On some hosts perithecia are rare. It is thought that the mycelium remains alive over winter.

Hosts: Amelanchier, Cratægus, Diospyros, Prunus, Pyrus,

Spirea and Vaccinium. Especially damaging to cherry and apple. Throughout the northern hemisphere.

P. tridactyla (Wal.) De Bary is considered by Salmon[110] as a variety of the last species. Hosts: Plum and other species of Prunus and of Spirea.



FIG. 133.—P. oxycanthae, appendage tips. After Salmon.

Similar to the preceding in habit and general character but differing in more critical characters. Perithecia 70–105 μ; cells 10–15 μ; appendages 2–8 usually 4, 1 to 8-times the diameter of the perithecium, apical in origin, more or less erect, apically 3–5 or 6-times dichotomously branched, primary branches usually more or less elongate, sometimes slightly recurved; asci globose or subglobose, 60–78 x 60–70 μ; spores 8, 20–30 x 13–15 μ.

Chiefly European but found also in Asia and America.

P. leucotricha (E. & E.) Salm.

Mycelium amphigenous, persistent, thin, effused; perithecia densely gregarious, rarely more or less scattered, 75–96 μ, subglobose, cells 10–16 μ; appendages of two kinds, one set apical the other basal; apical appendages 3–11 in number, more or less widely spreading, or erect-fasciculate, 4 to 7-times the diameter of the perithecium, apex undivided and blunt or rarely once or twice dichotomously branched, brown basally; basal appendages nearly obsolete or well developed, short, tortuous, pale brown, simple or irregularly branched; ascus oblong to subglobose, 55–70 x 44–50 μ, spores 22–26 x 12–14 μ, crowded in the ascus.

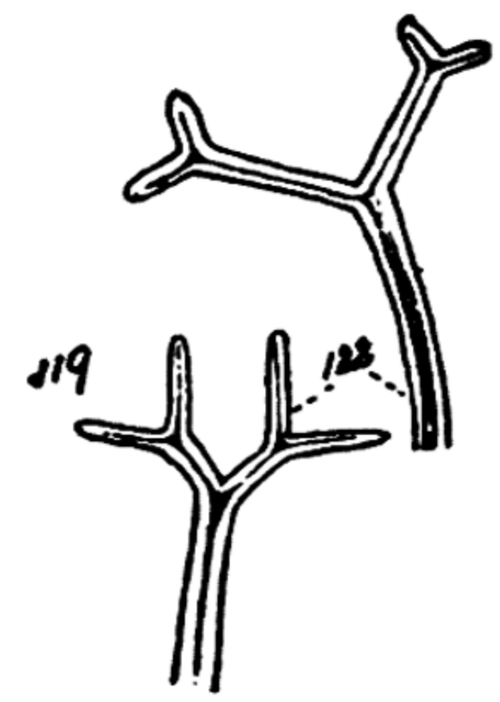


FIG. 134.—P. leucotricha, appendage tips. After Salmon.

Conidia (=Oidium farinosum): ellipsoid, truncate, hyaline, 28–30 x 12 μ.

Primarily American but occurring in Europe and Japan. A most serious pest of the apple. This and P. oxyacanthæ, the apple mildews of America, have been variously treated by writers so that the literature presents an almost inextricable tangle as has been pointed out by Pammel[343] and by Stewart,[331] Podosphæra oxyacanthæ being frequently reported instead of P. leucotricha. Sphærotheca mali and Podosphæra oxyacanthæ have also been much confused, due

to similarity of habit and the frequent abnormal development of the appendages, so that the published references are not always reliable.

Microsphæra Léviellé (p. 175)

Perithecia globose to subglobose; asci several, 2 to 8-spored; appendages not interwoven with the mycelium, branched in a definite manner at the apex, usually dichotomously and often very ornately, rarely undivided or merely once dichotomous.

According to Salmon [46] there are thirteen species; Engler and Prantl [7] recognize thirty.

M. grossulariæ (Wal.) Lév.

Epiphyllous or amphigenous; mycelium evanescent or subpersistent; perithecia scattered or densely aggregated, globose-depressed, 65–130 μ; cells 14–20 μ; appendages 5–22, colorless, 1–1¾ times the diameter of the perithecium, 4 to 5-times closely dichotomously branched, branches of first and second order very short, all segments deeply divided, tips not recurved; asci 4–10, broadly ovate or oblong, usually with a very short stalk, 46–62 x 28–38 μ; spores 4–6, rarely 3, 20–28 x 12–16 μ.

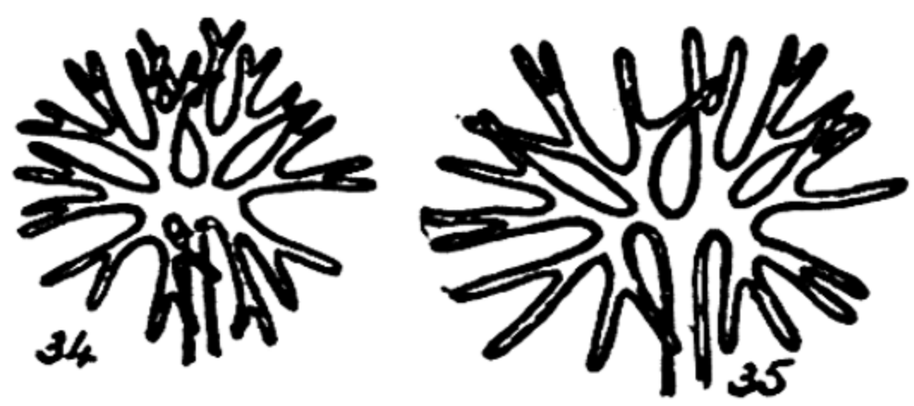


FIG. 135.—M. grossulariæ, appendage tips. After Salmon.

On five species of Ribes and two of Sambucus. This is the common European gooseberry-mildew, which is not common in America except on the elder.

M. berberidis (D. C.) Lév. occurs on the barberry in Europe and Asia.

M. alni (Wal.) Salm.

Amphigenous; mycelium evanescent or persistent; perithecia scattered to gregarious, globose-depressed, very variable in size, usually small, 66–110 μ, or even up to 135 μ; cells 10–15 μ wide; appendages variable in number (4–26) and length, $^1/_3$ to 2½ times the diameter of the perithecium, more or less rigid, colorless throughout or amber-brown at base, apex variously

(but not always) more or less closely 3 to 6-times dichotomously branched, tips of ultimate branches regularly and distinctly recurved; asci 3–8, ovate to ovate-globose, 42–70 x 32–50 μ, usually but not always short stalked; 4 to 8-spored; spores 18–23 x 10–12 μ.



FIG. 136.—M. alni, appendage tips. After Salmon.

This species is the most variable of the Erysipheæ showing large latitude in number of spores in the ascus, in length, color and branching of appendages, in size of perithecia. It occurs upon very numerous hosts. The economic ones on which it is most common are: Syringa, Lonicera, Alnus, Betula, Quercus, Carya, Castanea, Juglans, Platanus.

It is confined to the northern hemisphere.

Salmon recognizes in addition to the typical form six varieties. Those of economic importance are:

(a) **extensa** (C. & P.) Salm., a robust form on various American species of oaks;

(b) **calocladophora** (Atk.) Salm., also a robust form on American oaks but having pseudo-trichotomously branched appendages and large spores;

(c) **vaccinii** (Schw.) Salm., in America on Catalpa and various genera of Ericaceæ is a small-spored, long-appendaged form. It includes M elevata on Catalpa;

(d) **loniceræ** (D. C.) Salm., on species of Lonicera in Europe.

M. diffusa C. & P.

Amphigenous; mycelium persistent, thin and effused, or subpersistent and forming vague patches, or quite evanescent; perithecia scattered or gregarious, globose-depressed, very variable in size, 55–126 μ in diameter, averaging 90–100 μ, cells 10–20 μ wide; appendages very variable in number and length, 4–30, or rarely crowded and as many as 50, 1½ to 7-times the diameter of the perithecium, smooth, aseptate or 1 to 3-septate in the lower half, colorless or pale brown towards the base, flaccid when long, thin-walled above, becoming thick-walled towards the base, apex 3 to 5-times dichotomously or subdichotomously divided, branching diffuse and irregular, branches of the higher orders sub-nodulose, often apparently lateral, tips of ultimate branches not recurved;

asci 4–9, 48–60 x 28–30 μ, ovate-oblong with a very short stalk; spores 3–6, usually 4, 18–22 x 9–11.

Hosts: Desmodium, Glycyrrhiza, Lespedeza, Phaseolus, Symphoricarpos.

M. betæ Vanha [111] has recently been described as a species injurious to the beet. It is said to resemble E. polygoni but that cross inoculation between the beet and clover could not be made.

M. ferruginea Erik. is found on cultivated Verbenas [112] in Sweden.

M. euphorbiæ (Pk.) B. & C. occurs on various hosts in America and Asia, including Astragalus, Colutea, Cuphea and Euphorbia. Its only economic importance is as the cause of a disease of the roselle [26] and cowpea [113] on which it is very common.

Amphigenous; mycelium usually subgeniculate; perithecia gregarious in floccose patches or scattered, 85–145 μ, rarely 180 μ, cells 10–15 μ; appendages 7–28, usually narrow, more or less flexuose and nodose, 2.5 to 8 times the diameter of the perithecium, colorless above, 3 to 4-times dichotomously branched, branching irregular and lax; asci 4–13, rarely up to 26, ovate or ovate-oblong, short-stalked, 48–66 x 26–35 μ; spores usually 4, rarely 3, 5 or 6, 16–21 x 10–12 μ.

Phyllactinia Léveillé (p. 175)

Perithecia large, globose-depressed to lenticular; asci many, 2 or 3-spored; appendages equatorial, rigid, acicular, with a bulbous base; apex of perithecium with a mass of densely crowded branched outgrowths.

Typical epidermal haustoria are not produced but the mycelium sends special branches through the stomata into the intercellular spaces of the leaf.[114] These branches attain some length and constitute a limited internal mycelium, a character that is considered by some as of sufficient importance to set the genus apart in a separate family. The internal mycelium gives off haustoria which penetrate cells of the mesophyll. The appendages exhibit striking hygroscopic movements and aid in dissemination.

Only one species is recognized by Salmon.

P. corylea (Pers.) Karst.

Hypophyllous or rarely amphigenous; mycelium evanescent

or more or less persistent; perithecia usually scattered, rarely gregarious, 140–270 μ, rarely up to 350 μ; cells rather obscure, 15–20 μ; the apical outgrowth becomes mucilaginous attaching the perithecium firmly to places where it may fall; appendages

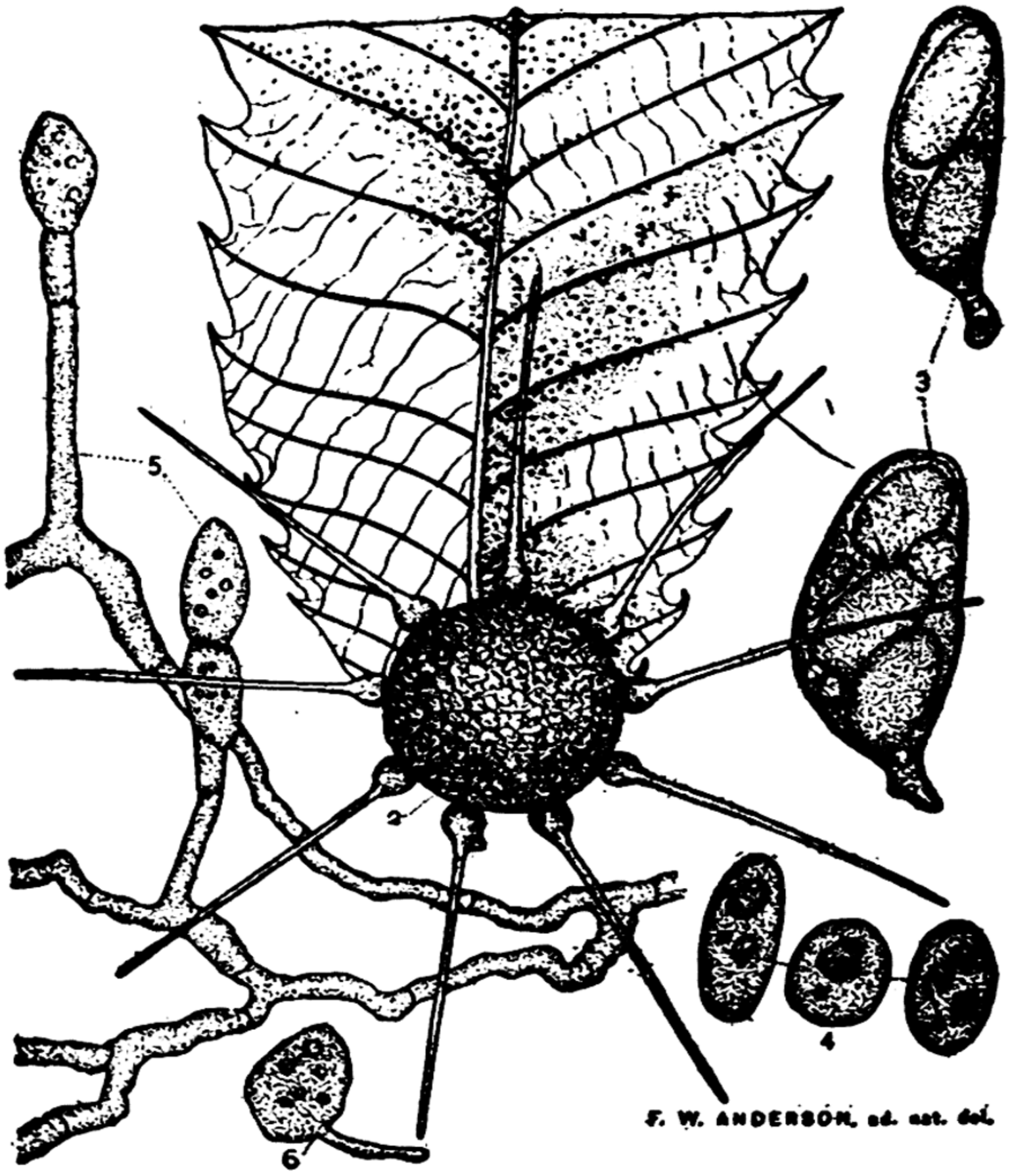


FIG. 137.—Phyllactinia corylea. 1. Natural size, on chestnut leaf. 2. Perithecium enlarged. 3. Two asci. 4. Three spores. 5. Conidia-bearing hyphae. 6. Conidium germinating. After Anderson.

5–18, equatorial, 1 to 3-times the diameter of the perithecium; asci 5–45, subcylindric to ovate-oblong, 60–105 x 25–40 μ, more or less stalked, 2, rarely 3-spored; spores 30–42 x 16–25 μ.

Conidia (=Ovulariopsis) acrogenous, solitary, hyaline, subclavate.

On Magnolia, Liriodendron, Berberis, Xanthoxylum, Ilex, Celastrus, Acer, Desmodium, Cratægus, Heuchera, Ribes, Hamamelis, Fraxinus, Asclepias, Catalpa, Cornus, Ulmus, Betula, Alnus, Corylus, Ostrya, Carpinus, Quercus, Castanea, Fagus and Typha.

Perisporiaceæ (p. 170)

Aërial mycelium covering the substratum with a dark growth, rarely absent, usually astromate. Perithecia on the mycelial threads or on a stroma, black, more or less globose, without opening or appendages, although in some genera (Meliola, etc.) mycelial outgrowths from the base of the perithecium simulate appendages. Asci elongate, numerous; spores various; paraphyses none.

Chiefly parasites, although several genera are saprophytes. About three hundred species.

Aside from ascospores, in some species conidia of one or several forms are known. These may be borne in pycnidia or uncovered on hyphæ. Apiosporium is especially rich in the number of its conidial forms.

Key to Genera of Perisporiaceæ

Spores 1-celled	
Spores not curved	
Spores hyaline	1. **Anixia.**
Spores brownish	2. **Orbicula.**
Spores curved, green	3. **Pseudomeliola.**
Spores 2-celled	
Spores, at least when immature, appendaged	4. **Zopfiella.**
Spores not appendaged	
Perithecia borne on the aërial mycelium	
Spores not enlarging after maturity	
Spores smooth	
Aërial mycelium prominent	5. **Dimerosporium,** p. 191.
Aërial mycelium none, or poorly developed	
Asci cylindric-clavate; parasites	6. **Parodiella.**
Asci saccate, large; saprophytes	7. **Zopfia.**
Spores finely echinulate	8. **Marchaliella.**
Spores enlarging after maturity	9. **Richonia.**
Perithecia borne on a hairy stroma	10. **Lasiobotrys,** p. 191.
Spores 3 or more celled	
Aërial mycelium none or poorly developed	

Spores with cross walls only
Spores elongate to cylindric
Spores 4-celled, saprophytes. ..... 11. **Perisporium.**
Spores 4 to 8-celled; parasites. .... 12. **Schenckiella.**
Spores needle-formed. ..... 13. **Hyaloderma.**
Spores muriform
Spores brown ..... 14. **Cleistotheca.**
Spores hyaline..... 15. **Saccardia.**
Aërial mycelium prominent
Spores with cross walls only
Spores hyaline
Saprophytic. ..... 16. **Scorias.**
Parasitic..... 17. **Zukalia,** p. 191.
Spores brown
Perithecia without apparent appendages
Perithecia rounded, opening irregularly. ..... 18. **Antennaria,** p. 192.
Perithecia elongate, clavate, opening by regular slits.. 19. **Apiosporium,** p. 191.
Perithecia appearing to have appendages
Stromatic..... 20. **Limacinia,** p. 193.
Not stromatic..... 21. **Meliola,** p. 193.
(Some species of Meliola have muriform spores)
Spores muriform
Spores with an appendage at each end. ..... 22. **Ceratocarpia.**
Spores not appendaged
Subicle crustose. ..... 23. **Capnodium,** p. 192.
Subicle radiate. ..... 24. **Pleomeliola,** p. 193.

The genera of interest as pathogens induce disease rather by covering, shading and smothering leaves with dense sooty-black coatings than by parasitizing their hosts. They are not strictly speaking parasites but live saprophytically upon the surfaces of leaves, fruit and twigs often subsisting upon insects or insect exudations, the so called "honey dew."

Dimerosporium Fuckel (p. 189)

Perithecia depressed-globose, membrano-carbonous; asci clavate to ovate, 8-spored; spores 2-celled, hyaline or brownish; mycelium abundant, dark, forming a film and often bearing conidia on conidiophores.

D. mangiferum Sacc. does some harm to the mango.

D. pulchrum, Sacc. grows upon the leaves of several woody plants, such as privet, Lonicera, Carpinus and Cornus. Conidia=Sarcinella heterospora.

D. collinsii (Schw.) Thüm., forms witches brooms on the service berry.



FIG. 138.—Dimerosporium pulchrum, *F*, conidia; *G*, ascus. After Winter.

Lasiobotrys Kunze (p. 189)

Perithecia superficial, globose, minute, black, aggregated in botryose fashion, stromate; asci cylindric, 8-spored; spores oblong, 2-celled, hyaline.

The one species **L. loniceræ** Kze. forms dark coatings on honeysuckle leaves in Europe, North Africa and Siberia but does little or no harm.

Zukalia Saccardo (p. 190)

This genus is like Meliola except in its hyaline spores and in its perithecium.

Z. stuhlmanniana is on seedling cocoanuts and other palms.

Apiosporium Kunze (p. 190)

Perithecia superficial, minute, globose to pyriform, membranous or carbonous; asci ovate to clavate, 8-spored; spores globose to oblong, hyaline; paraphyses none. Conidia=Torula, Fumago, Chætophoma, etc.

Several forms are known to constitute sooty coatings on leaves of woody plants, subsisting on insect secretions. The specific limitations in the genus have not been satisfactorily worked out owing to the comparative rarity of the ascigerous stages.

A. salicinum. (Pers.) Kze. is common on leaves of many species of woody plants.

Perithecia brownish, gregarious, globoid-oblong, composed of

minute cells as in the Erysiphaceæ; spores ovate, guttulate, hyaline, 10 x 8 μ; conidia of various kinds, formed from the bases of the perithecia, (a) multicellular macroconidia, (b) unicellular microconidia, (c) gemmæ.

A. brasiliense Noack is reported on grape [337] in Brazil.

Various species also occur on numerous woody and herbaceous plants which are infected with aphids or upon which their "honey dew" falls.

Antennaria Link differs but little from Apiosporium.

A. pithyophila Nees. occurs on leaves of fir; **A. elæophila** Mont.

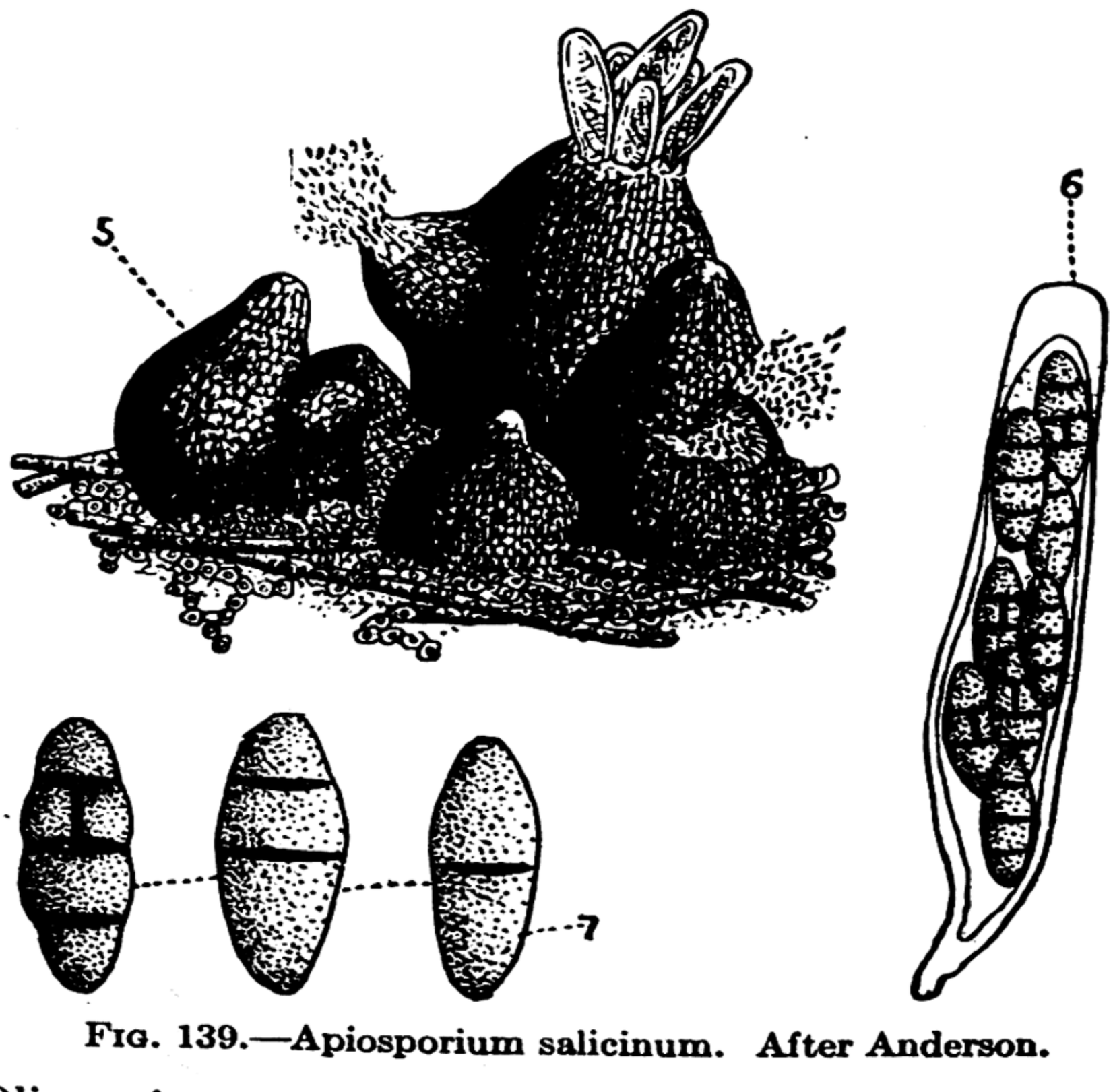


FIG. 139.—Apiosporium salicinum. After Anderson.

on the Olive; **A. setosa** Zimm. on coffee; **A. footi** B. & D. commonly on green house plants; **A. piniphilum** Fcl. on fir.

Capnodium Mont. (p. 190)

This is easily distinguished from genera of similar habit by its muriform spores.

C. quercinum Pers. occurs on oak; **C. taxi** S. & R. on Taxus; **C. fœdum** Sacc. on Oleander; **C. coffeæ** Del. on coffee; **C. tiliæ**

Fcl. on Tilia; **C. citri** B. & P. on leaves of citrus fruits in Europe and America.

C. stellatum Bern. and **C. guajavæ** Bern. cause sooty mold on various trees in the tropics;[333] **C. corticolum** McAlp. on citrous trees in New South Wales[338] and Australia; **C. javanicum** Zimm., on coffee.[339] **C. meridionale** Arnaud is on Oleander, oak, and olive, in Europe;[340] **C. olea** Arnaud[341] on olive in France.

Limacinia tangensis P. Henn. is on the mango and cocoanut in Africa.

Pleomeliola hyphænes P. Henn. is on leaves of Hyphæne in Africa.

Meliola Fries (p. 190)

Perithecia globose, surrounded by dichotomously branched hyphæ which resemble the appendages of the Erysiphaceæ; asci short, broad, 2 to 8-spored; spores oblong, 2 to 5-septate, rarely muriform; paraphyses none.

This is a genus of over one hundred thirty species, whose mycelium grows superficially upon leaves and twigs.

M. camelliæ (Catt.) Sacc. occurs on Camellia.

Mycelium, copious, black, bearing various sporing bodies; perithecia black, spherical, 80–150 μ., containing several 8-spored asci; spores 16–18 x 45 μ, olivaceous, 4-celled. Stylospores ovoid, 5 μ, hyaline, borne in flask-shaped pycnidia which may be as much as 1 or 2 mm. high; pycnidia globose resembling the perithecia but smaller, containing spherical spores of about the same size as the stylospores. Chlamydospores are also formed by the breaking up of

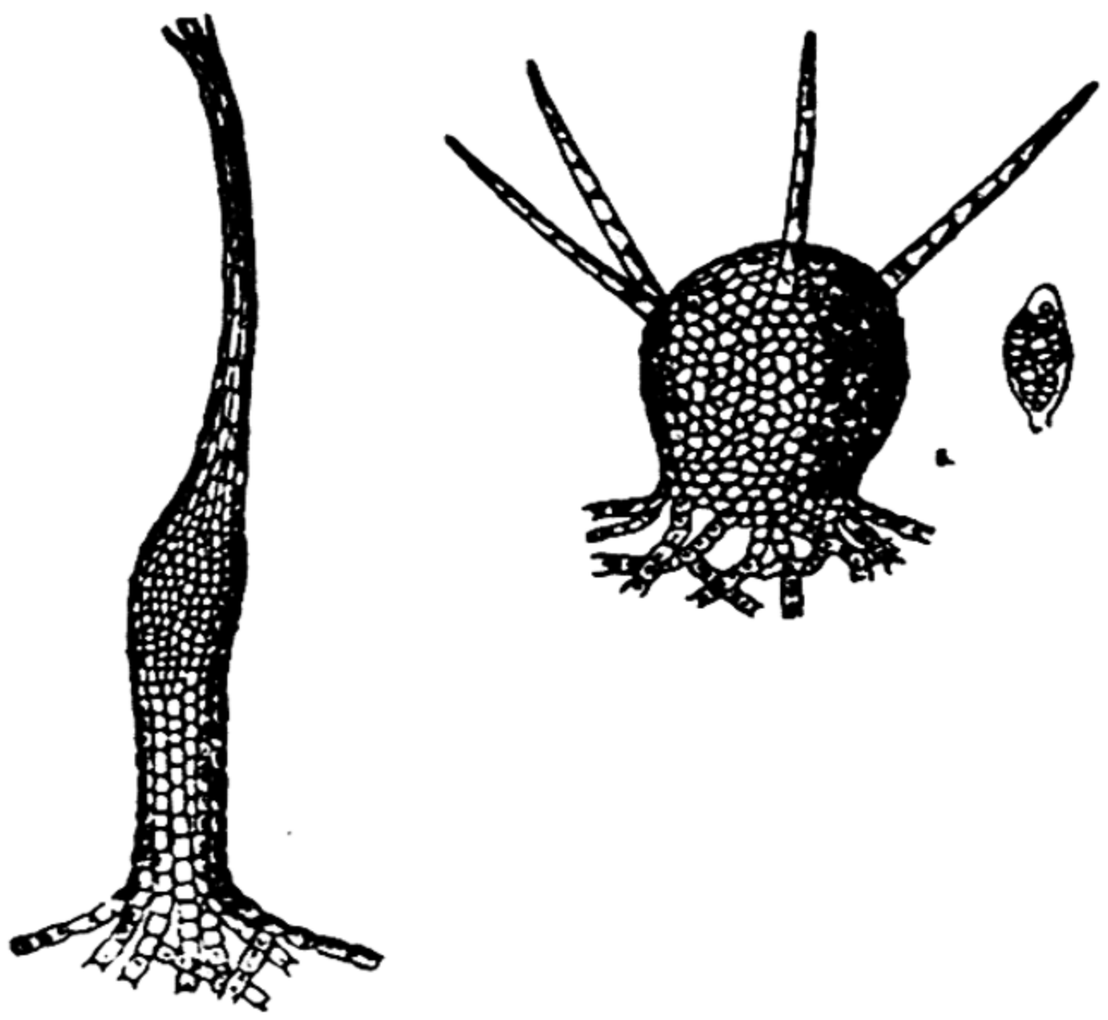


FIG. 140.—M. camelliæ. 3, pycnidium and spores. 4, other form of pycnidium. 5, perithecium, ascus and ascospores. After Webber.

the mycelium. Fumago camelliæ Catt. is a conidial form of this species.

M. penzigi Sacc.[115-117] is found on Citrus forming a sooty black mold. It subsists on "honey dew," following principally certain insects as Aleyrodes, Ceraplastes, Dactylopius, and Aphis. The species is quite similar to the preceding.

The hyphæ are from olive-green to dark brown and when old are connected into a compact membrane. The fungus is entirely superficial, possessing, however, small knob-like projections for attachment and large discs (**hyphopodia**). Reproduction is by conidia, pycnidia, stylospores and perithecia.

Webber says:

"Several forms of conidia are produced, some being but slight modifications of the common cells of the mycelium, while others are compound spores. Pycnidia are small, spherical black reproductive bodies, about 40 μ in diameter, and are usually present in considerable numbers in the mycelium. They may be readily seen with a strong magnifying hand lens, but cannot be definitely distinguished from perithecia or the young stages of the stylospores. Stylospores are borne in conceptacles, which in their simplest form resemble flasks with long drawn-out necks. Frequently, however, they are much branched, and as they project from 1 to 2 mm. beyond the mycelium they form quite a conspicuous part of the fungus. They are easily recognized with the unaided eye, and can be seen with considerable distinctness with a hand lens. Perithecia are black, spherical reproductive bodies closely resembling pycnidia, from which they can not be distinguished with a hand lens. However, they are larger, being eighty micro millimeters in diameter. Each perithecium contains several asci and each of these bears eight ascospores. Some of the investigators who have studied this disease have failed to find perithecia, and only twice has the writer found them in his examination of material from Florida.

"The various reproductive bodies other than perithecia, particularly the conidia and stylospores, are developed in great abundance."

M. niessleanea Wint. is common on Rhododendron.

Several entomogenous fungi[117-119] have been found which by preying upon those insects which secrete honey dew, lessen the injury

from all sooty molds. Among these are the genera Aschersonia [117] and Sphærostilbe.

Microthyriaceæ (p. 170)

Mycelium superficial, dark; perithecia superficial, separate, shield-shaped, unappendaged, black, membranous to carbonous, formed of radiating chains of cells; asci 4 to 8-spored, short; paraphyses usually present.

A family of over twenty genera and more than three hundred species, chiefly poorly understood.

Only two species have been noted as serious economic pathogens; **Scolecopeltis æruginea** Zimm. and **Microthyrium coffæ** both on coffee in Africa.

The genera of the Ascomycetes which remain to be treated, and which are separated from those preceding by the possession of an **ostiole,** are by some known under the name **Pyrenomycetes.** Cf. p. 170. There are three orders, the Hypocreales, Dothidiales and Sphæriales.

Hypocreales (p. 124)

The chief character separating this order from other Pyrenomycetes is the brighter color—yellow, purple, scarlet, red, etc.—and the more tender texture of its perithecia,—soft, fleshy, cottony, patellate or effused.

The perithecium also differs from that of the preceding orders in the possession of a distinct opening, **ostiole,** for the exit of spores.

Perithecia globose to cylindric or flask-shaped, free on the substratum (rarely subepidermal) or united by a common matrix, which varies from a cottony subiculum to a distinct fleshy stroma, wall membranous or at least not truly carbonous; asci cylindric, clavate or subovoid, mostly 4 to 8-spored but often becoming 16-spored by the separation of each original spore into two globose or subglobose cells; spores simple or compound, hyaline or colored, globose to filiform.

Conidia are usually produced freely, each genus usually possessing at least one form of free-borne conidia, while in some genera several different kinds of conidia are found. Pycnidia are rare. Often the ascigerous stage is nearly suppressed and rare while one or more of the conidial forms predominates.

Such form genera as Verticillium, Tubercularia, Sphacelia, Sphærostilbe and Isaria are connected with the Hypocreales.

The order includes some sixty genera, and over eight hundred species. Of these only a half dozen genera contain important plant parasites, another half dozen genera, parasites of less importance. The rest are saprophytes, insect parasites, etc., of no economic significance.

Opinion differs as to the characters which should be made the basis for subdivision of this family, whether to throw main stress upon the structure of the perithecium or upon the character of the spores.

Following Lindau [7] the order contains a single family, **Hypocreaceæ,**[121-122] which may be divided into six subfamilies. According to a more recent treatment of the American members of the group by Seaver [62, 120] two families and four tribes are recognized. Lindau's tribes Hyponectrieæ, Hypomyceteæ, and Melanosporeæ are united with a part of Nectrieæ under the last name while the remaining genera, referred by Lindau to this tribe, constitute the tribe Creonectreæ. These tribes constitute the family Nectriaceæ. The remaining tribes, Hypocreeæ and Clavicipiteæ with about the same limits constitute the family Hypocreaceæ.

Key to Tribes of Hypocreaceæ

Perithecia at first sunken in the substratum, later erumpent.	**1. Hyponectrieæ.**
Perithecia not sunken in the substratum; stroma present or absent	
Stroma cottony, never fleshy; perithecia immersed in the stroma, or borne on its surface.	**2. Hypomyceteæ.**
Stroma fleshy or wanting	
Spores dark colored; perithecia free on the substratum (in some species of Melanospora with a cottony stroma) scattered.....	**3. Melanosporeæ.**
Spores hyaline, yellow or red	
Perithecia without a stroma, or on a fleshy stroma.....	**4. Nectrieæ,** p. 197.

Perithecia sunken in a fleshy stroma
  Spores not filiform; perithecia half or entirely sunken in the stroma, and distinct from it.. 5. **Hypocreeæ,** p. 198
  Spores filiform; perithecia completely embedded in the stroma and not clearly distinct from it..... 6. **Clavicipiteæ,** p. 199.

The first tribe contains no parasitic genera while the second and third contain but one each. Of the Hypomyceteæ, the genus **Hypomyces** (p. 200) is set off from the others by its 2-celled hyaline fusiform spores, and its cottony stroma. Of the Melanosporeæ the genus **Melanospora** (p. 200) is distinguished by the long beaks of its flask-shaped perithecia, which are brown rather than black, and its brown 2-celled spores.

KEYS TO THE GENERA OF **Nectrieæ, Hypocreeæ** AND **Clavicipiteæ**

TRIBE IV. **Nectrieæ** (p. 196)

Conidiophores not of the Stilbum type
  Spores elongate, 1-celled; perithecia free on the substratum; stroma none
    Spores not appendaged
      Perithecia yellow or red
        Asci cylindric; ostiole concolorous with the perithecium..... 1. **Nectriella.**
        Asci clavate-cylindric; ostiole darker than the perithecium.. 2. **Thelocarpon.**
      Perithecia violet or blue..... 3. **Lisiella.**
    Spores appendiculate..... 4. **Eleutheromyces.**
  Spores elongate, 2 to many-celled
    Spores with cross walls only
      Spores 2-celled
        Asci 8-spored; often with 1-celled, conidia formed in the ascus
          Perithecium yellow or red
            Spores hyaline..... 5. **Nectria,** p. 201.
            Spores brown..... 6. **Neocosmospora,** p. 205.
          Perithecium blue or violet..... 7. **Lisea.**

Asci many-spored
Perithecium fleshy, ostiole elevated. . . . . 8. **Metanectria.**
Perithecium hard, ostiole sunken 9. **Cyanocephalium.**
Spores 2 to many-celled
Spores not appendiculate
Perithecium bright colored, not blue. . . . . 10. **Calonectria,** p. 205.
Perithecium blue or violet. . . . . 11. **Gibberella,** p. 206.
Spores appendiculate, 4-celled
Perithecia clavate, ostiole wartlike. . . . . 12. **Paranectria.**
Perithecia flask-shaped, ostiole elongate. . . . . 13. **Lecythium.**
Spores muriform
Perithecium bright colored, not blue. . . . . 14. **Pleonectria,** p. 207.
Perithecia dark colored or blue. . . 15. **Pleogibberella.**
Spores filiform
Perithecia fleshy, bright colored. . . . . 16. **Ophionectria,** p. 207.
Perithecia horny, brown. . . . . 17. **Barya.**
Conidiophores of the Stilbum type, stroma wanting .
Spores 2-celled. . . . . 18. **Sphærostilbe,** p. 207.
Spores 4-celled. . . . . 19. **Stilbonectria.**
Spores muriform. . . . . 20. **Megalonectria.**

Tribe V. Hypocreeæ (p. 197)

Stroma sunken in the substratum or grown to it, usually free later
Spores 1-celled. . . . . 21. **Polystigma,** p. 207.
Spores 2-celled. . . . . 22. **Valsonectria,** p. 208.
Spores several-celled by cross walls. . . . . 23. **Cesatiella.**
Spores muriform
Spores hyaline. . . . . 24. **Thyronectria.**
Spores olive-brown. . . . . 25. **Mattirolia.**
Stroma from the first separable from the substratum
Spores 1-celled. . . . . 26. **Selinia.**
Spores 2-celled
Cells of the spores separating in the ascus

Stroma patellate or effuse. . . . . 27. **Hypocrea,** p. 209.
Stroma erect, simple or branched. . . 28. **Podocrea.**
Cells of the spores not separating in the ascus
Stroma patellate or effuse. . . . . 29. **Hypocreopsis.**
Stroma erect, branched. . . . . 30. **Corallomyces.**
Spores 3 to many-celled
Stroma bright or dark colored, not conidia-bearing. . . . . 31. **Broomella.**
Stroma dark, green or black, with conidia
Conidia of two kinds. . . . . 32. **Loculistroma,** p. 215.
Secondary conidia absent. . . . . 33. **Aciculosporium,** p. 211
Spores muriform. . . . . 34. **Uleomyces.**

Tribe VI. **Clavicipiteæ** (p. 197)

Stroma effused
Stroma forming a sheath about the host. 35. **Epichloë,** p. 210.
Stroma flat, tuberculate, or disk-shaped
Stroma not conidia-bearing
Stroma thick, usually light colored.. 36. **Hypocrella.**
Stroma thin, black. . . . . 37. **Dothiochloë,** p. 210.
Stroma with the inner portion conidia-bearing. . . . . 38. **Echinodothis,** p. 211.
Stroma erect
Stroma small, saccate, membranous. . . . 39. **Oömyces.**
Stroma large, erect, with distinct sterile and fertile portions, the latter often knob-like
Stroma formed in the bodies of insects and spiders, or in subterranean fungi. . . . . 40. **Cordyceps.**
Stroma formed in the inflorescence of Glumaceæ, etc., spores continuous
Stroma not growing from a sclerotium. . . . . 41. **Balansia,** p. 209.
Stroma growing from a sclerotium after a period of rest
Asci preceded by conidia. . . . . 42. **Claviceps,** p. 211.
Asci preceded by smut-like chlamydospores. . . . . { 43. **Ustilaginoidea,** p. 213.
44. **Ustilaginoidella,** p. 114.

Hypomyces Fries (p. 197)

Stroma an effused cottony subiculum, often of considerable extent; perithecia numerous, usually thickly scattered and immersed in the subiculum, rarely superficial; asci cylindric, 8-spored; spores fusoid or fusiform, usually apiculate, rarely blunt, 2-celled, hyaline; conidial phase variable.

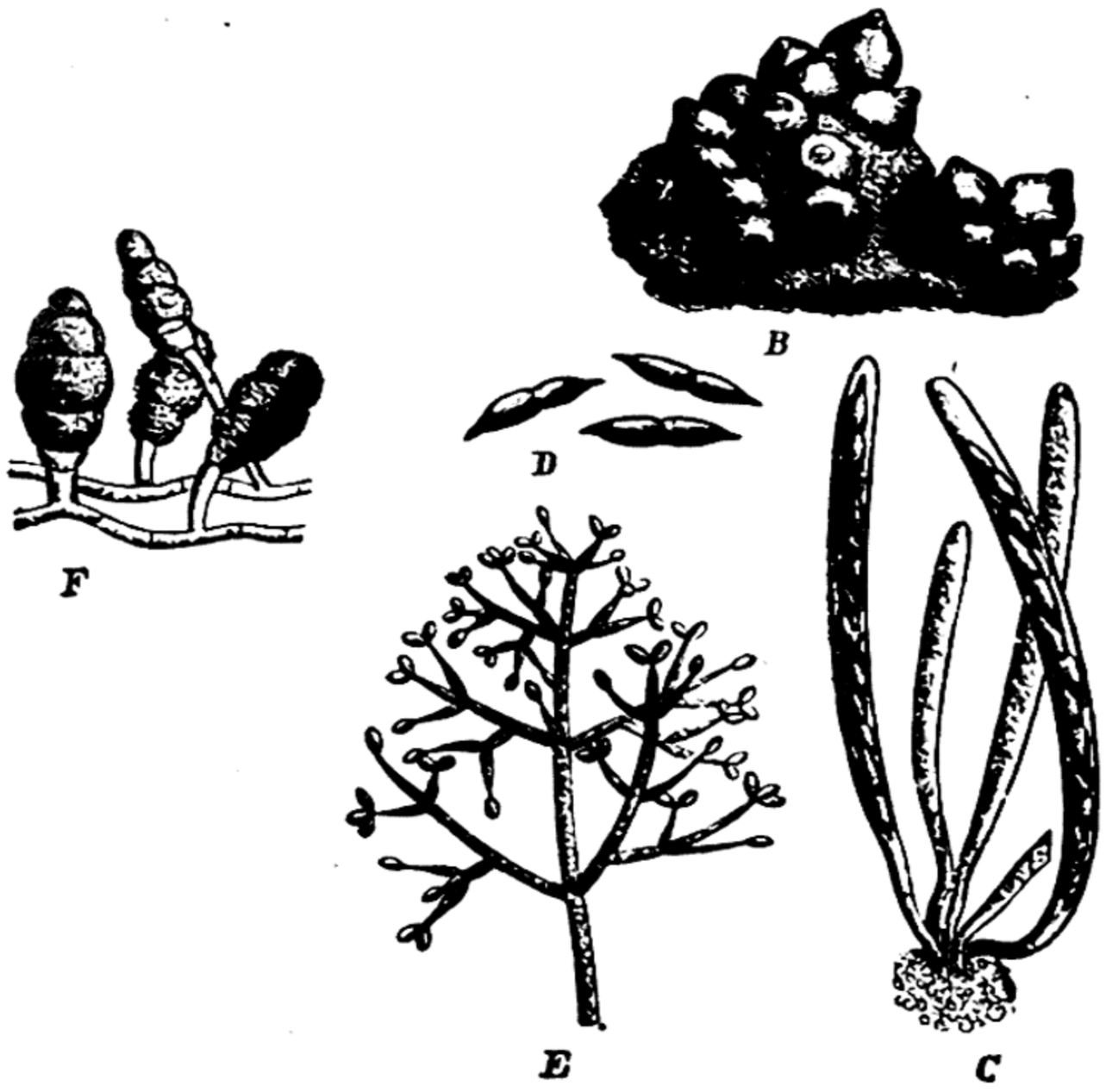


FIG. 141.—Hypomyces ochraceus. *B*, perithecia; *C*, asci and spores; *D*, spores; *E*, conidia; *F*, chlamydospores. After Tulasne.

This genus of some forty species contains but few saprophytes, the majority being parasitic, chiefly on the larger fungi. The genus is of economic interest only as affecting mushrooms, though one species, **H. hyacinthi** has been found causing secondary infection in onions,[19] following a bacterial trouble, and another; **H. solani** Reinke follows a similar disease on potatoes. Chlamydospores and conidiospores develop, belonging to various form genera as Verticillium, Mycogone, Fuligo, Diplocladium, Dictylium, Sepedonium, Blastotrichum.

Allied to this genus are probably **Mycogone rosea** and **M. perniciosa,** which are destructive enemies of mushroom culture.

Melanospora Corda (p. 197)

Perithecia superficial, without a stroma, globose-pyriform or flask-shaped, with a long neck which is usually clothed at the tip with a fringe of hairs, perithecia often hairy; asci broadly clavate, 4 to 8-spored; spores 1-celled, brown to brownish-black.

The genus contains some forty species, mostly common saprophytes.

M. damnosa (Sacc.) Lin. is serious on wheat and rye.[123, 124]

M. stysanophora Mat. is said to be an ascigerous stage of Dematophora glomerata, cf. p. 230, so injurious to the grape.

Nectria Fries (p. 197)

Stroma absent or tubercular, fleshy, bright colored; perithecia single, or gregarious, on or in the stroma or among cottony hyphæ, globose or ovate, walls fleshy, yellow, red or brown, smooth or hairy; ostiole papillate or not; asci cylindric or clavate, 8-spored; spores elongate blunt or pointed, hyaline, rarely red, 2-celled, forming conidia in the ascus; paraphyses usually none.

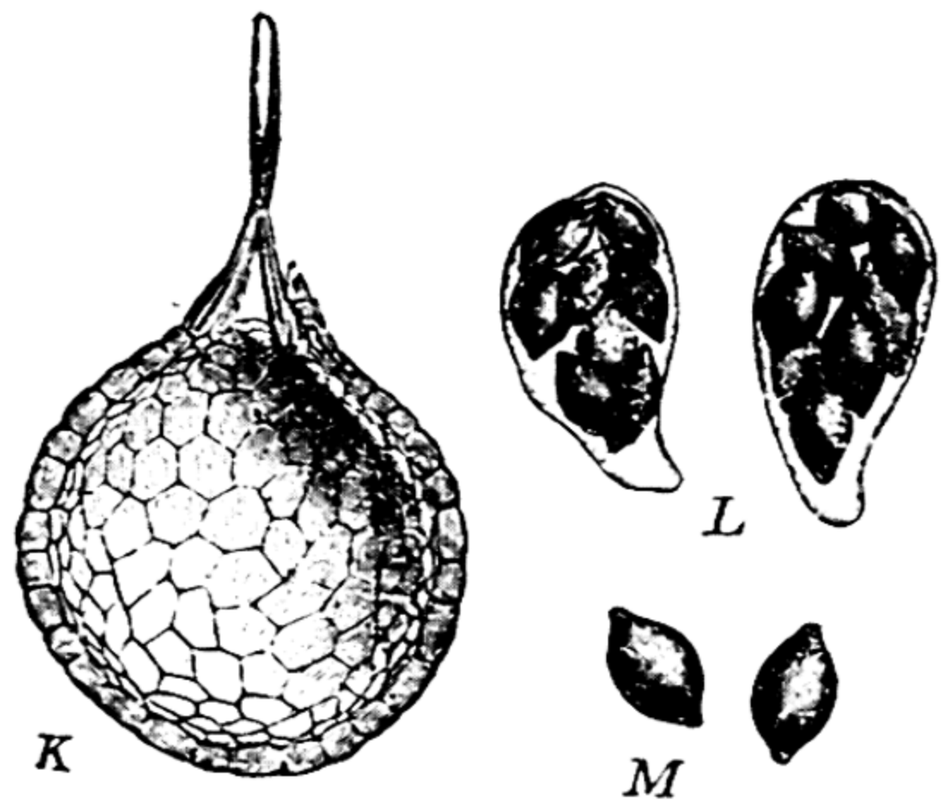


FIG. 142.—Melanospora. *K*, perithecium; *L*, asci; *M*, spores. After Lindau.

As conidial stages occur the form genera Cephalosporium, Tubercularia, Fusarium, Spicaria, Fusidium and Chætostroma. Much doubt exists as to specific limitations, and as to the life histories of the species. Some two hundred fifty species have been described. Several are credited with causing serious diseases, most of them occurring as wound parasites and unable to effect entrance into sound tissue. Other species are pure saprophytes and harmless.

The genus Nectria is divided into seven sub-genera, which are frequently given generic rank, as follows:

KEY TO SUBGENERA OF **Nectria**

Spores smooth
- Perithecia smooth
  - Stroma fleshy. . . . . 1. **Eunectria,** p. 202.
  - Stroma a cottony subiculum. . . . . 2. **Hyphonectria.**
  - Stroma usually absent; perithecia scattered. . . . . 3. **Dialonectria,** p. 205.
- Perithecia hairy. . . . . 4. **Lasionectria.**
- Perithecia scaly. . . . . 5. **Lepidonectria.**

Spores tuberculate. . . . . 6. **Cosmonectria.**

Spores appearing striated, golden brown . . . 7. **Phaeonectria.**

The majority of economic species belong to the first subgenus.

Eunectria (p. 201)

N. cinnabarina (Tode) Fr.

Stroma erumpent, tubercular, at first pinkish or yellowish-red, darker with age, 1–2 mm. high and broad; perithecia almost globose, the ostiole rather prominent, becoming slightly collapsed, at first bright cinnabar-red, darker with age, granular, 375–400 μ in diameter; asci clavate, 50–90 x 7–12 μ; spores mostly 2-seriate, elliptic elongate, ends obtuse, slightly curved, 12–20 x 4–6 μ; paraphyses delicate.

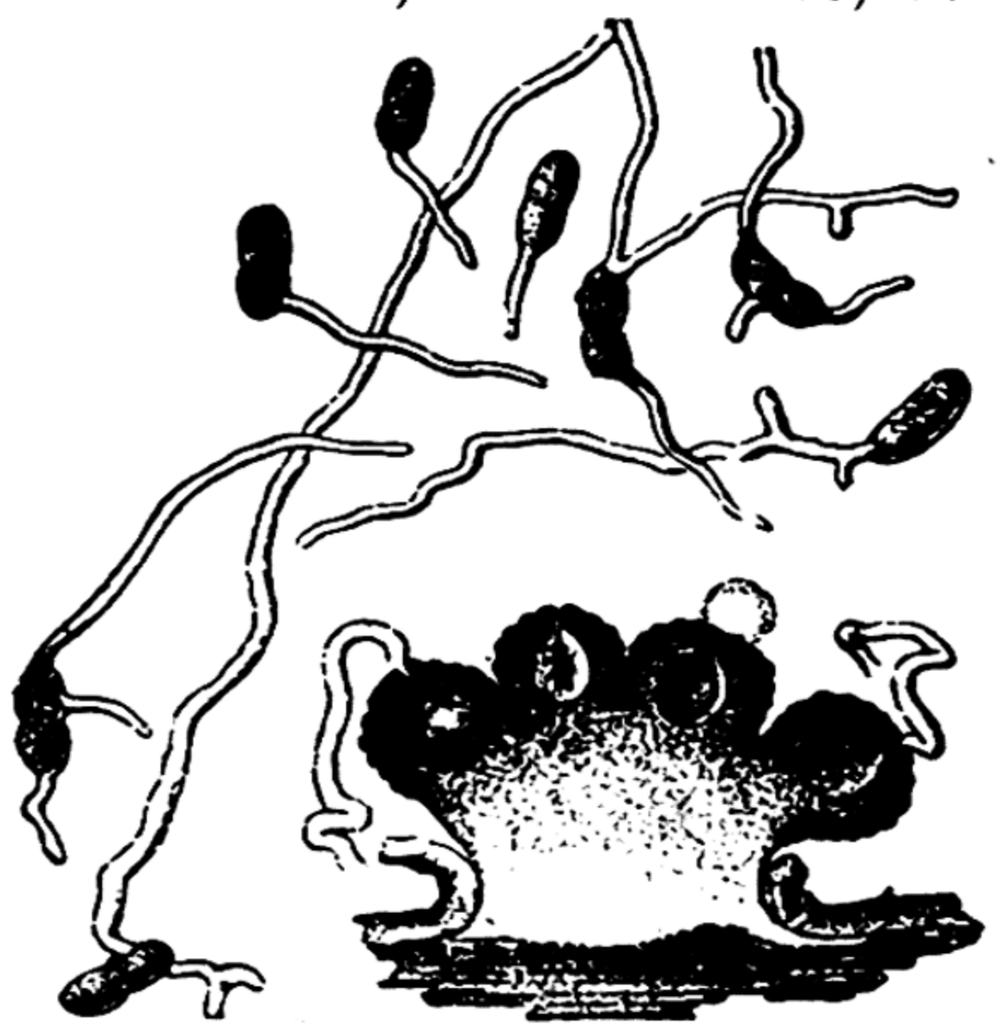


FIG. 143.—N. cinnabarina, perithecia in stroma, ascospores issuing in cirri; germinating spores. After Hartig.

Tubercularia vulgaris borne on the stroma is the conidial stage. Conidiophores aggregated into tubercular masses each 50–100 μ long; conidia on short lateral branches, elliptic, hyaline, 4–6 x 2 μ.

The closely septate delicate hyphæ grow rapidly through the wood or bark, penetrating nearly every cell and turning the wood black and collecting to form stromata on or in the bark. These stromata in fall or spring break through the epidermis and produce warty, gray to pink, excrescences, which at first bear profuse conidia both terminally and laterally on short stalks and later dark-red ascigerous structures; though the latter are much less common and are often absent. The fungus is said to be unable to affect living cambium and cortex.

It is found saprophytically on many decayed woody plants that have been frost killed, and parasitically on pear, Tilia, Æsculus, China berry, Betula, Ribes, Acer, Carya, Morus, Prunus, Quercus, Ulmus, etc. Mayer [128] germinated spores on a cut branch; the mycelium spread to and killed the main stem; tubercles appeared and during the following year perithecia developed on these tubercles. In America the species has attracted attention on the currant [125, 126] in which host the mycelium invades chiefly the

cambium. On this host, however, it is now said to be non-parasitic.[127]

Durand,[126] culturing the conidial form on sterile currant stems, observed the formation of tubercles with abundant conidia after about fourteen days. On agar conidia were produced directly from single hyphæ without any stroma. Perithecia were found in the field on the tubercles with the conidia in February.

N. ditissima Tul.

Stroma light colored; perithecia cespitose, densely and irregularly clustered, or rarely scattered, ovate, ostiole prominent, bright red, smooth or roughened; asci cylindric to clavate, 80–90 x 8–10 μ; spores fusoid, 12–16 x 4–5 μ.

The unicellular microconidia are followed by falcate, multicellular, macroconidia (Fusidium candidum), which are borne on pale stromatic cushions.

Common on dicotyledonous trees, especially beech, oak, hazel, ash, alder, maple, lime, apple and dogwood, where it is usually a wound parasite, particularly common after hail. It is especially well known from Europe [13] and has more recently attracted attention in America.

The mycelium does not usually advance more then one centimeter in each year. It is believed that it can travel within the wood and break through the cambium and cortex at points some distance from the place of original infection, thus producing new spots. Very minute conidia produced in the bark aid in tissue decomposition. White conidial (Fusidium) stromata appear near the periphery of affected spots and here, too, in groups or scattered, appear the deep red perithecia.

N. cucurbitula Sacc.

Perithecial clusters erumpent, often irregular in form, 1–2 mm. in diameter; perithecia densely clustered, bright red, ovate, with a prominent ostiole, rarely collapsing; asci cylindric to clavate 75–100 x 6–8 μ; spores at first crowded and partially 2-seriate, finally becoming 1-seriate, lying obliquely in the ascus, broad, fusoid, rarely subelliptic, 14–16 x 5–7 μ.

Its hosts are spruce, fir, pine and other conifers in Europe and North America.

The fungus is usually a wound parasite, often following hail.

Germ tubes from ascospores or conidia enter the cortex and develop a rich mycelium in the sieve tubes and soft host. This advances most rapidly during the dormant period of the bast.



FIG. 144.—N. ipomœæ, a cluster of perithecia. After Halsted.

White or yellow stromata the size of a pin-head appear and bear numerous conidia. Later come the red perithecia whose ascospores ripen in winter or spring.

N. ribis (Tode) Rab.

Cespitose, stroma compact; perithecia subglobose, smooth; ostiole papillate; asci subclavate, 90–100 x 15; spores elongate or fusoid, hyaline, 1-septate, 18–20 x 5–6 mm. On currant.

N. ipomœæ Hals.

Perithecia clustered, ovate, roughened, red; asci cylindric-clavate; spores elliptic; conidial phase (Fusarium) appearing as a white mold-like covering of the host; conidia several-celled, falcate.

Halsted [129] inoculated sterilized egg-plant stems with the Nectria spores and the Fusarium form developed, followed by the ascigerous stage. Ascospores in hanging drop were also seen to give rise to the Fusarial stage. The Nectrias found upon egg-plant and sweet potato, morphologically alike, were proved by cross inoculations to be identical.

N. rousselliana Tul. and **N. pandani** Tul. are parasitic on Buxus and Pandanus respectively,[27] the former with the conidial stage. Volutella buxi.

N. solani Ren. & Bert. is said by Massee to be the ascigerous form of Fusarium solani.[22]

Perithecia crowded on a stroma, minute, conic-globose, smooth, blood-red; asci clavate; spores hyaline, 8–9 x 5 μ; paraphyses slender, tips strongly clavate.

Conidia (=Fusarium solani) hyaline, 3 to 5-septate, fusiform, 15–40 x 5–8 μ, but very variable, borne on erect, simple or branched conidiophores.

N. coffeicola Zimm. is on cacao and vanilla; **N. bainii** Mas. **N. amerunensis** A. & Str. and Petch. are reported parasitic on cacao [130] pods. The three latter names are probably synonyms of the first.



FIG. 145.—N. ipomœæ, the Fusarium stage. After Halsted.

N. diversispora

N. vandæ Wah. and **N. goroshankiniana** (Wah.) grow on cultivated Vanda: **N. theobromæ** Mass., probably identical with **N. striatospora** Zimm., is found on cacao trunks as is also **N. jungeri** Henn.

N. bulbicola. Henn. is on orchids and **N. gigantispora** Zimm. on Ficus.

Dialonectria (p. 201)

N. graminicola B. & B., the conidial stage of which is Fusarium nivale is destructive to winter wheat and rye in Europe.[131]

Less known are **N. bogoriensis** Bern and **N. vanillæ** Zimm. on vanilla; **N. luteopilosa** Zimm. and **N. fruticola** Zimm. on coffee; [136] **N. theobromicola** Mass. on Theobroma.



FIG. 146.—N. ipomœæ, an ascus. *b*, *c*, *d*, germination of ascospores. After Halsted.

Neocosmospora E. F. Smith was reported by Smith [132] as the ascigerous form of Fusarium vasinfectum and consequently as the cause of many serious wilt diseases. Recent work by Higgins [133, 134] and by Butler [135] has shown that in all probability there is no genetic connection between these forms and that the fungus under discussion is merely a harmless saprophyte.

Calonectria (p. 198)

Perithecia free, often closely gregarious, true stroma wanting but perithecia often surrounded by a radiate, white mycelium which may simulate a stroma; perithecia globose to ovate, red or yellow; asci elongate, 8-spored; spores elongate, more than 2-celled. About sixty species.

C. pyrochroa (Desm.) Sacc., has been reported parasitic on Platanus.[19] Its conidial stage is Fusarium platani.

C. flavida Mass. is in the West Indies on cacao causing canker.

C. cremea Zimm. with Spicaria colorans, Corymbomyces albus,

Clanostachys theobromæ [137] probably as its conidial stages, is on fruits and stems of cacao.

C. bahiensis Hem. reported in South America on cacao stems is really an Anthostomella; **C. gigaspora** Mass.[54] is found on sugar-cane.

Gibberella Saccardo (p. 198)

Stromata tuberculate, more or less effused; perithecia cespitose or occasionally scattered on or surrounding the stroma; asci clavate, 8-spored; spores fusoid, 4 to many-celled, hyaline; conidial phase a Fusarium.

Of the thirteen species but few are parasitic.

G. saubinetii (Durieu & Mont.) Sacc. [138, 139]

Perithecia gregarious, leathery membranous, verrucose, ovate, subpedicellate, bluish, papillate, 200–300 x 170–220 μ; asci oblong clavate, acuminate, 60–76 x 10–12 μ; spores one or obliquely two-ranked, fusiform, curved or straight, acute, 4-celled, 18–24 x 4–5 μ; mycelium effused, crustose, white to rose colored. Conidia (=Fusarium) solitary, or clustered, fusiform, curved, acute or apiculate, 5-septate, hyaline, 24–40 x 5 μ.



FIG. 147.—G. saubinetii; 2, Fusarium spores, 5, the asci. After Selby.

Many species of Fusarium, e. g., F. culmorum, F. avenaceum, F. hordei, F. heterosporum, have been referred to this ascigerous stage. Spherical stylospores are also reported.[140]

The mycelium and the conidial stages often coat the grains and heads of cereals with red or pink. Perithecia are rare as shining dark dots on the grains in the late season. The Fusarium stage also is said to cause a clover and alfalfa disease and the fungus by inoculation and culture is shown to be identical on wheat, clover, barley, rye, spelt, emmer, and oat. It is carried from season to season on infected seed and causes large loss of young plants. Doubt as to the relationship of the Fusarial forms mentioned with the ascigerous stages has been raised by the work of Appel and Wollenweber. See also Fusarium (p. 646).

G. cerealis Pass., the cause of a serious wheat disease in Italy [141] may be identical with the last species.

G. moricola Ces. & d. Not. grows on Morus.

Pleonectria Saccardo (p. 198)

Perithecia cespitose or separate, globose, pale, papillate; asci 8-spored; spores many-septate, muriform, hyaline.

P. berolinensis Sacc., which occurs on various species of wild and cultivated currants both in Europe and America has been reported by Durand [126] as associated with a currant trouble in New York.

P. coffeicola Zimm. attacks coffee.

Ophionectria Saccardo (p. 198)

Stroma globose, tubercular, depressed or none; perithecia superficial, clustered or scattered; asci cylindric to clavate, 2 to 8-spored; spores 4 to many-celled, fusoid to subfiliform, hyaline or subhyaline.

About fourteen species. **O. coccicola** E. & V. attacks scale insects and is said also to cause gummosis of oranges.[142] **O. foliicola** Zimm. is found on coffee.

Sphærostilbe Tulasne (p. 198)

Stroma a slender stalk with a globose or conical head; perithecia bright colored, membranous, globose, subglobose or ovate; asci cylindric or subcylindric, 8-spored; spores 2-celled, elliptic or subelliptic, hyaline. Conidial phase Stilbum, Atractium or Microcera.

Some twenty species. **S. repens** B. & Br. in India causes a root disease of Hevea [143] and arrowroot.

S. flavida Mass.[22] causes disease of coffee in tropical America.

Polystigma De Candolle (p. 198)

Stroma fleshy, effused, red or reddish-brown, growing on leaves; perithecia sunken, only the ostiole being above the surface, thin, leathery, hyaline; asci elongate, clavate, 8-spored; spores ellipsoid, 1-celled, hyaline. Three species.

P. ruba (Pers.) D. C. causes reddish spots on the leaves of Prunus. Stroma at first bearing pycnidia (Libertella rubra) with filiform hooked, continuous conidia. Perithecia produced on old leaves, bearing ellipsoid to elongate asci; spores 10–13 x 6 μ, smooth.



FIG. 148.—P. rubrum. *D*, asci; *E*, conidia. After Fisch.

The invaded leaf tissue is colored by the mycelium which bears a reddish oil. Numerous perithecia are immersed in the diseased area and, opening to the surface, extrude spores which seem incapable of infecting. During winter the stroma darkens, turns hard and produces the perithecia and ascospores. Ascogonium and trichogyne-like organs have been described.[144]

P. ochraceum (Wahl.) Sacc. occurs on Prunus padus.

Valsonectria Spegazzini (p. 198)

Stroma thin, cushion-shaped, under the bark of the host; perithecia similar to those of Valsa, sunken in the stroma, the beak erumpent, red; asci cylindric, 8-spored; spores 2-celled, hyaline or light brown.

A genus of but three species which differ from Valsa chiefly in their red color. [347

V. parasitica (Murr.) Rehm.[328, 329,

Pustules numerous, erumpent, at first yellow, changing to brown at maturity; perithecia usually ten to twenty in number, closely clustered,

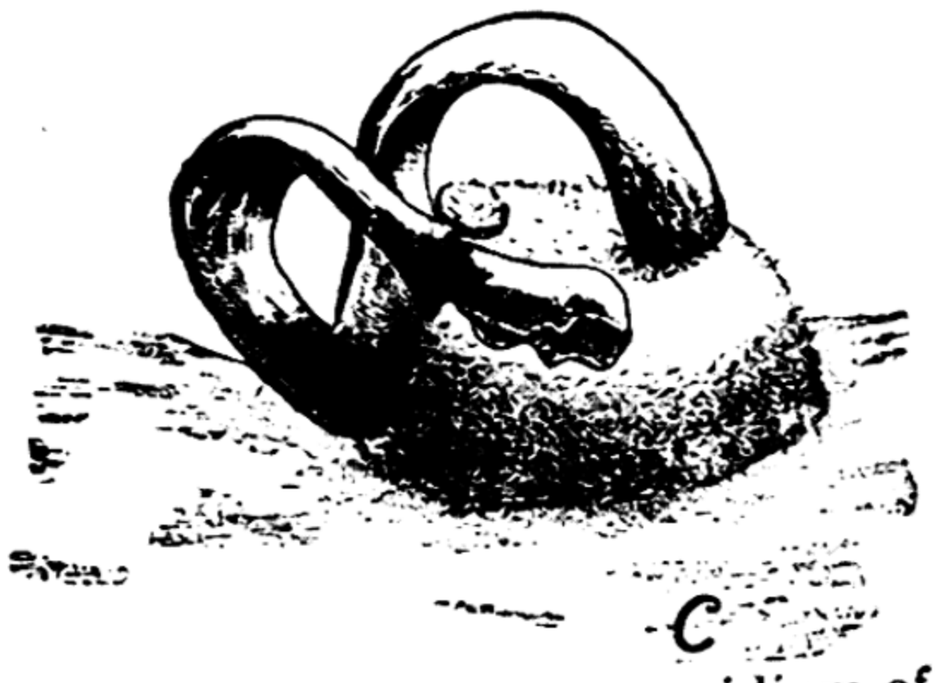


FIG. 149.—Showing a pycnidium of Valsonectria and the manner in which the spores issue from it. After Murrill.

flask-shaped, deeply embedded in the stroma in the inner bark, scarcely visible to the unaided eye; necks long, slender, curved, with thick black walls and rather prominent ostiola; asci oblong-clavate, 45–50 x 9 μ, 8-spored; spores usually biseriate, hyaline, oblong, rounded at the ends, often slightly constricted, uniseptate, 9–10 x 4–5 μ. Summer spores very minute, 1 x 2–3 μ, pale-

yellowish, cylindrical, slightly curved, discharged in twisted threads as in Cytospora.

This fungus, originally described as Diaporthe parasitica, is a serious parasite on the chestnut. The mycelium grows through the inner bark in all directions from the initial wound at which infection occurred, eventually girdling the part. The wood is also affected. The perithecia appear in abundance upon or in cracks of the bark, extruding their spores in greenish to yellow threads.

Hypocrea Fries (p. 199)

Stroma subglobose to patellate, fleshy or subfleshy; perithecia entirely immersed, subglobose to ovate, the necks slightly protruding; asci cylindric, originally 8-spored, spores breaking each into two so that the asci at maturity contain sixteen hyaline spores. About one hundred ten species.

H. ceretriformis Berk. occurs on the bamboo in Tonkin;

H. sacchari on sugar cane.

Balansia Spegazzini (p. 199)[145]

Sclerotium composite, formed of the affected parts of the host embedded in a well developed mass of fungous tissue; stroma arising from the sclerotium, stipitate and capitate or sessile, pulvinate, obovate, discoid, or separated from the sclerotium as soon as the latter is mature, surface slightly papillate from the projecting ostiola of the immersed scattered perithecia; asci 8-spored; paraphyses none. Conidia, when known, an Ephelis and preceding the stroma.

B. hypoxylon (Pk.) Atk. occurs on various grasses, chiefly in the southern United States. **B. claviceps** Speg. infests Setaria and Pennisetum in tropical lands. The remaining species, chiefly of warm regions, are mostly grass inhabiting.

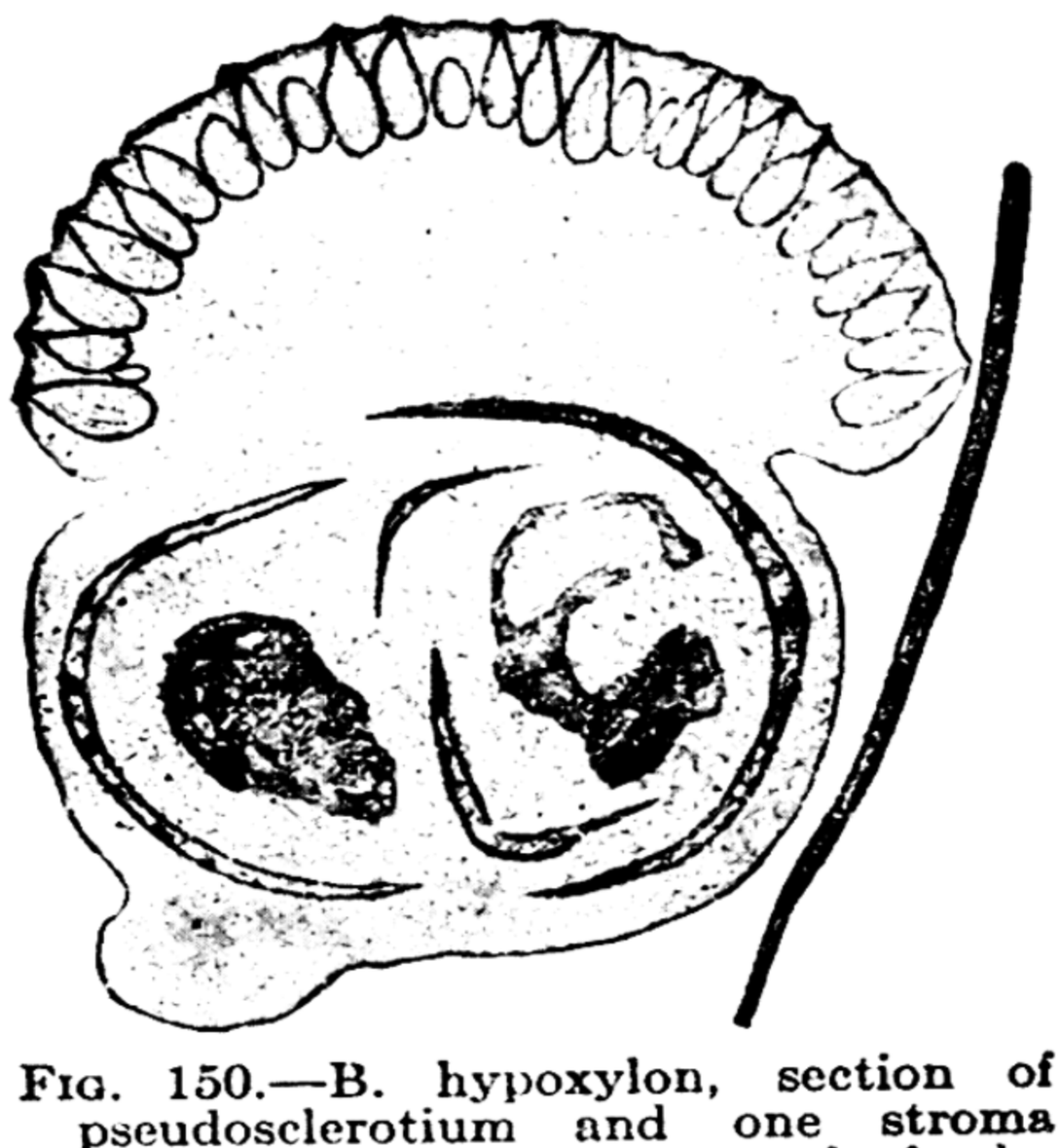


FIG. 150.—B. hypoxylon, section of pseudosclerotium and one stroma showing perithecia, stem, leaf elements and an ascus. After Atkinson.

Dothichloe Atkinson (p. 199)[145]

Stroma thin, hard when dry, black, especially the outer portion, lighter within, effuse, pulvinate, disciform or armilla-form, partly or entirely surrounding the host; perithecia crowded, confluent with the stroma, but the thin walls of distinctive structure, immersed, the apex projecting; asci cylindric, 8-spored; spores filiform, septate at maturity, and eventually separating at the septa into short segments.

Like the preceding genus, both species **D. atramentosa** (B. & C.) Atk. and **D. aristidæ** Atk. are grass inhabitors of warm regions of the United States. The former is the commoner species with a wider range of hosts.

Epichloe (Fries) Tul. (p. 199)

Stroma effused, subfleshy, at first pale, becoming bright orange, sheathing the host; perithecia immersed or with the ostiola protruding; asci cylindric, 8-spored; spores filiform, many-celled. Of some nine species only one is important.

E. typhina (Pers.) Tul. Stroma effused, at first pale, becoming bright orange, forming sheaths 2–5 cm. long around stems of various grasses, often destroying the inflorescence; perithecia thickly scattered, partially or entirely immersed in the stroma, soft, membranous, concolorous with the stroma, the ostiole rather prominent; asci very long; spores almost as long as the ascus, closely fasciculate, multiseptate, about 2 μ in diameter; conidia elliptic, hyaline, 4–5 x 3 μ, preceding the perithecia on the stroma.

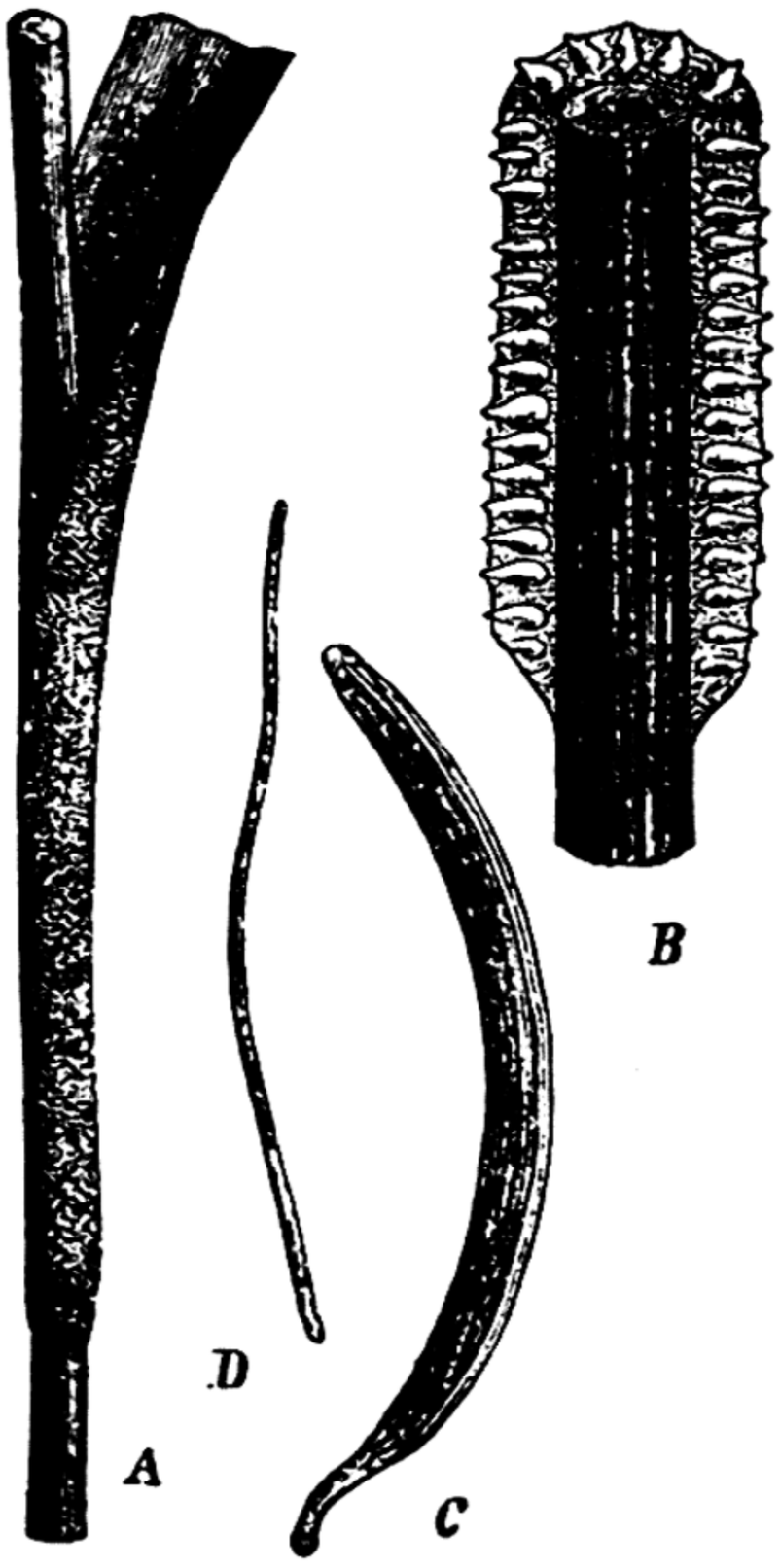


FIG. 151.—Epichloe. *A*, habit on grass; *B*, stroma in long section; *C*, ascus; *D*, ascospore. After Winter, Brefeld and Lindau.

Many grasses are affected, often to serious extent. The mycelium shows first as a yellowish cobwebby growth surrounding the leaf sheath and soon develops a conidial stroma. Later the stroma

turns to orange-color and the perithecia appear, forming a layer.

Echinodothis Atkinson (p. 199) [336]

Stromata subfleshy or corky, light-colored, pulvinate to subglobose or irregular in form, often constricted at the base, sometimes entirely surrounding the host, consisting of several layers of different consistency; perithecia superficial, scattered, subcylindric, sessile, giving an echinulate appearance to the stroma; asci cylindric, 8-spored; spores linear, septate, at length separating at the septa into short segments.

Two species, parasitic on grasses in the warmer parts of the western hemisphere.

E. tuberiformis (Berk. & Rav.) Atk.[336]

Stromata subglobose, 1 cm. or more in diameter, entire, lobed, or divided, seated upon the reed or upon the leaf-sheath and fastened by a whitish mycelium consisting of radiating threads which are sometimes tinged yellowish-brown; substance leathery or corky, consisting of three layers, an inner layer white to pinkish, an intermediate layer light ochraceous and an outer layer cinnamon; stroma externally dark brownish becoming black; conidiophores needle-shaped; conidia ovoid to fusoid, 3–4 x 7–10 μ; perithecia entirely superficial in small clusters or evenly distributed over the exposed surface of the stroma, subconic in form, giving the whole stroma a spiny appearance, clothed except the apex with a dense covering of minute threads which are at first whitish, becoming cinnamon colored, the naked apex becoming black, about 0.3 x 1 mm.; asci cylindric, with a swelling at the apex, very large, 475–750 x 14–20 μ; spores nearly as long as the ascus, hyaline or slightly yellowish, many-septate, the joints 15 x 4–5 μ.

On Arundinaria in the Southern States.

Asciculosporium take Miy.[146] forms witches' brooms on bamboo in Japan. It is closely related to Dusiella and Epichloe.

Claviceps Tulasne (p. 199)

Sclerotium formed within the hypertrophied tissues of the ovary of the host, succeeding the conidial stage which is a Sphacelia; stroma erect, with a long sterile base and a fertile,

usually knot-like head; perithecia closely scattered, sunken in the stroma with only the ostiole protruding, flask-shaped, the walls scarcely distinguishable from the stroma; asci cylindric,

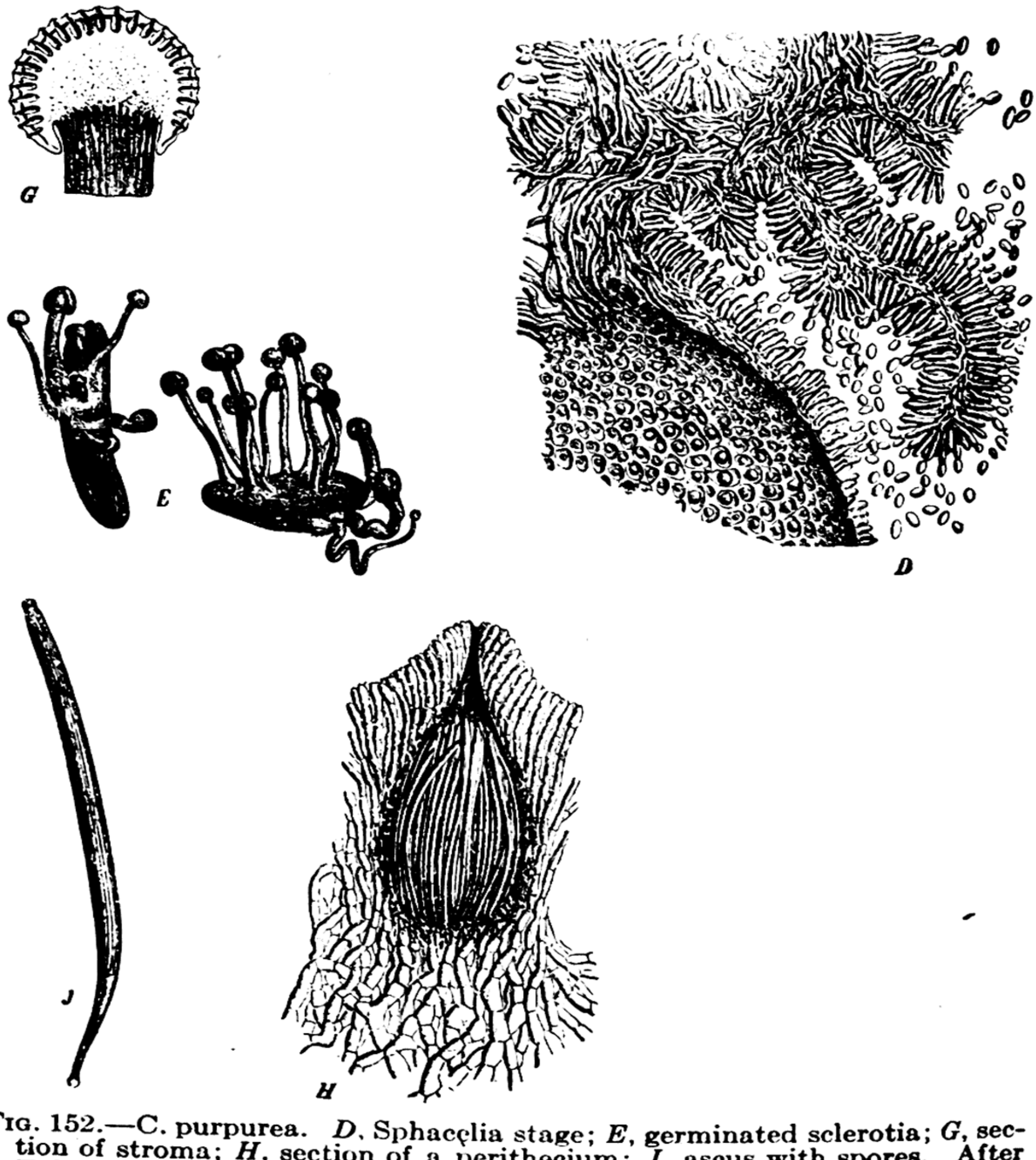


FIG. 152.—C. purpurea. *D*, Sphacelia stage; *E*, germinated sclerotia; *G*, section of stroma; *H*, section of a perithecium; *J*, ascus with spores. After Tulasne.

8-spored; spores hyaline, continuous. Some twelve or fifteen species are recorded all affecting the ovaries of the Gramineæ.

C. purpurea (Fr.) Tul.[147]

Sclerotium elongate, more or less curved, and resembling a much enlarged grain, after a period of rest producing few or many, clustered or scattered stromata which are 0.5–1.5 cm. high; spore

60–70 μ. long. Conidia (=Sphacelia segetum) produced on the grain before the sclerotium is formed, conidiophores short, cylindric, arranged in a compact palisade, bearing small, oval, hyaline, 1-celled conidia. Hosts, rye, wheat, oats and numerous other grasses.

Infection of the ovary at blooming time is followed by complete possession and consumption of the ovarial tissue by the mycelium, and by considerable development of stroma beyond the ovary. On the external much-folded part of this stroma, particularly at its distal end, are borne layers of conidiophores and numerous conidia and a sweet fluid is exuded. The conidia, carried by insects, spread summer infection. Later the stroma, losing a large part of the distal region, rounds off to a definite sclerotium, smooth, firm, blue to black in color, and several times larger than the normal grain of the host plant.

After a period of rest, usually lasting till the following season, the sclerotium gives rise to several stalked, capitate, perithecial stromata. The perithecia are arranged around peripherally, the ostioles protruding and giving the head a rough appearance. The sclerotium constitutes the ergot of pharmacy and contains a powerful alkaloid capable of causing animal disease if eaten.

This species appears to be differentiated into a number of biologic races.[148]

C. microcephala (Wal.) Tul. infects numerous grasses both in Europe and America, being especially destructive to blue grass.

Two species **C. paspali** S. & H. and **C. rolfsii** S. & H. have been reported on Paspalum.[149]

Ustilaginoidea Brefeld (p. 199)[150]

Sclerotium formed in the grain of the host, resembling superficially a smut sorus, in the center composed of closely interwoven hyphæ, externally the hyphæ are parallel, radiating towards the periphery and bearing echinulate, globose, greenish conidia; stroma with a long sterile stem and a fertile head; perithecia immersed in the stroma as in Claviceps; asci and spores also as in Claviceps.

Two species are known, one on Setaria which produces an ascigerous stage, the other on rice, the ascigerous stage of which

is not known but which is placed in this genus on account of the similarity of its conidial stage with that of the other species.

U. virens (Cke.) Tak. Ascigerous stage unknown, sclerotia spherical, about 5 mm. in diameter; conidia spherical, at first smooth-walled, hyaline, at maturity echinulate and olive green, 4–6 μ.

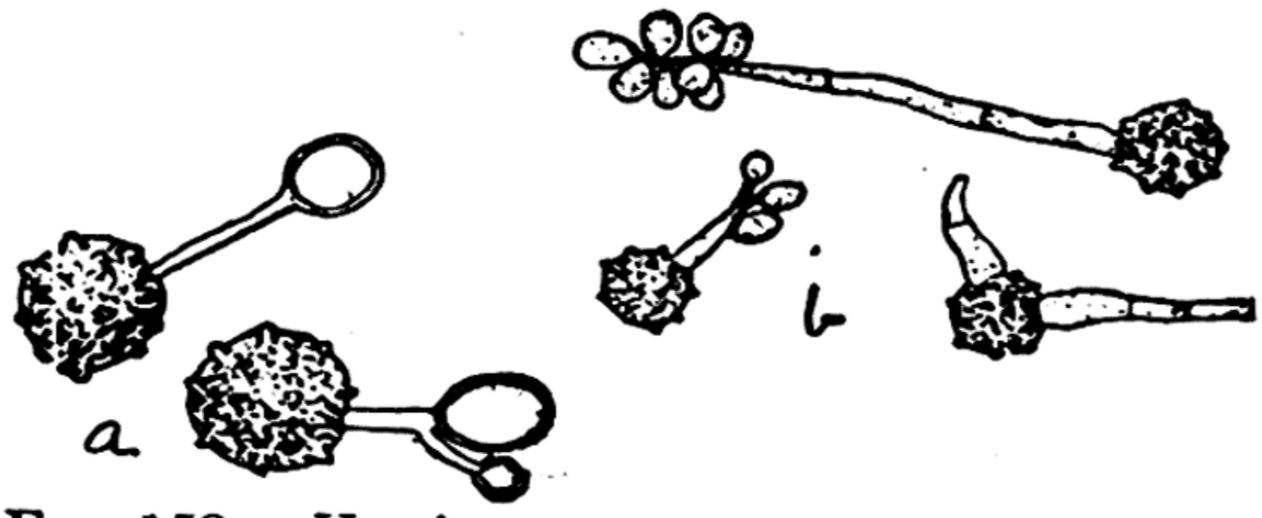


FIG. 153.—U. virens; *a*, spores germinated in water; *b*, germinated in bouillon. After Fulton.

The short thick walled hyphæ of the interior of the sclerotium are closely interwoven to a false tissue, toward the periphery they become parallel and are directed radially. Here a yellow layer is produced and spores are formed laterally on the hyphæ. When mature the spores are in mass dark olive-green and form an outer green layer on the sclerotium. The spores germinate in water, producing a vegetative mycelium which bears secondary spores and somewhat resembles the mycelium of the Ustilaginales.[151] Successful inoculations have not been made.

Ustilaginoidella Essed (p. 199)

This is a genus erected by Essed[302] to receive the species **U. musæperda,** which he regards as the cause of the "Panama disease" of bananas, at least as it occurs in Suriname.

Sclerotia similar to those of Ustilaginoidea are found; chlamydospores and conidia obtain, among the latter are some of marked Fusarium type; others are in pycnidia.

U. œdipigera Essed is also described by Essed[303] as the cause of another less important banana disease in Suriname and Columbia; a disease accompanied by hypertrophy of the base of the stem and leading to the common name "bigie footœ." This fungus differs from the last in its 1 to 2 to 3-celled conidia.

U. graminicola Essed causes a rice disease.[304] This species differs but slightly from the two preceding. Chlamydospores smaller, conidia 1 to 5-celled.

Loculistroma Patterson & Charles[152] (p. 199)

Stromata upright, sessile, at the nodes of the host, fleshy, soft, green or black, containing conidial chambers in which are produced hyaline filiform conidia and on the outer surface of which are borne Cladosporium-like conidia; perithecia scattered, partly immersed, ostiolate; asci clavate, cylindric, 8-spored; spores fusiform, 3 to many-septate, olivaceous, biseptate; paraphyses none. There is only one species known.

L. bambusæ. P. & C.[152]

Stromata 1 cm. long by 2 mm. in diameter; perithecia almost spherical, 125 x 100 μ; asci 45–50 x 9–10 μ; spores 22 x 4. 5–5 μ; primary conidia 14–16 x 0.75–1 μ; borne in chambers on basidia, 8 x 0.5 μ; secondary conidia external, 1 to 3-celled, borne on external olivaceous hyphæ.

It causes a witches' broom of bamboo (Phyllostachys sp.), in China. Infection probably occurs in the terminal node. The fully developed sclerotia-like structures, resembling those of Claviceps, are dark green to black when mature, and consist of a central hyaline sclerotial tissue in which are many round conidial chambers. Perithecia develop from the peripheral layer.

Dothidiales (p. 124)

There is only one family the **Dothidiaceæ.**

Mycelium developed in the substratum, septate, at length forming a thick, dense, very dark stroma in which the perithecia are sunken and with which their walls are completely fused, rarely partly free; asci borne from the base of the perithecium; paraphyses present or none.

The Dothidiaceæ contain some four hundred species and more than twenty-four genera. They differ from the last order in their firm black sclerotium-like stromata which are usually pale to white within. The perithecia are usually grouped together in great numbers in the external layer of the stroma, sunken in its undifferentiated body. Conidia of various forms are present.

KEY TO GENERA OF **Dothidiaceæ**

Stromata at first sunken later more or less free
Perithecia standing free on the stroma; spores at maturity, 4-celled, dark — 1. **Montagnella.**
Perithecia almost completely embedded in the stroma
Stromata variable, more or less irregular in outline but never elongate
Spores 1-celled
Spores hyaline
Asci typically borne at the base of the perithecium
Asci 8-spored
Spores ellipsoid
Perithecia few. . . . . — 2. **Mazzantia.**
Perithecia numerous. . — 3. **Bagnisiella.**
Spores filiform. . . . . — 4. **Ophiodothis.**
Asci many-spored. . . . . — 5. **Myriogenospora.**
Asci borne laterally at the equator of the perithecium, spores ellipsoid. . . — 6. **Diachora,** p. 217.
Spores brown. . . . . — 7. **Auerswaldia.**
Spores 2-celled
Spores hyaline
Spores ovate. . . . . — 8. **Plowrightia,** p. 217.
Spores needle-like. . . . . — 9. **Rosenscheldia.**
Spores colored
Cells of the spore similar. . . . — 10. **Roussœlla.**
Cells of the spore dissimilar. . — 11. **Dothidea,** p. 220.
Spores several-celled
Spores with cross walls only
Spores hyaline, 4-celled. . . . . — 12. **Darwiniella.**
Spores colored, multicellular — 13. **Homostegia.**
Spores muriform
Spores hyaline. . . . . — 14. **Curreyella.**
Spores colored. . . . . — 15. **Curreya.**
Stromata elongate, linear or lanceolate

Spores hyaline	
Spores 1-celled.	16. **Scirrhiella.**
Spores 2-celled.	17. **Scirrhia.**
Spores 4 to 8-celled, fusiform. . .	18. **Monographus.**
Spores colored, multicellular, fusiform.	19. **Rhopographus.**
Stromata sunken, permanently united to the epidermis and substratum	
Spores 1-celled.	20. **Phyllachora,** p. 220.
Spores 2-celled	
Spores of similar cells.	21. **Dothidella,** p. 221.
Spores of dissimilar cells.	22. **Munkiella.**
Stromata from the first superficial	
Stromata encrusted, widely spreading. . .	23. **Hyalodothis.**
Stromata cushion-shaped, limited.	24. **Schweinitziella.**

Of these genera only five are of interest as plant pathogens. The majority contain only saprophytes.

Diachora Müller (p. 216)

The genus is easily recognized by its peculiarity of bearing asci only as an equatorial band instead of on the floor of the perithecia, a character unique among the Pyrenomycetes.

D. onobrychidis (D. C.) Müll. is reported as causing black spots on leaves of sainfoin and Lathyrus in Europe.

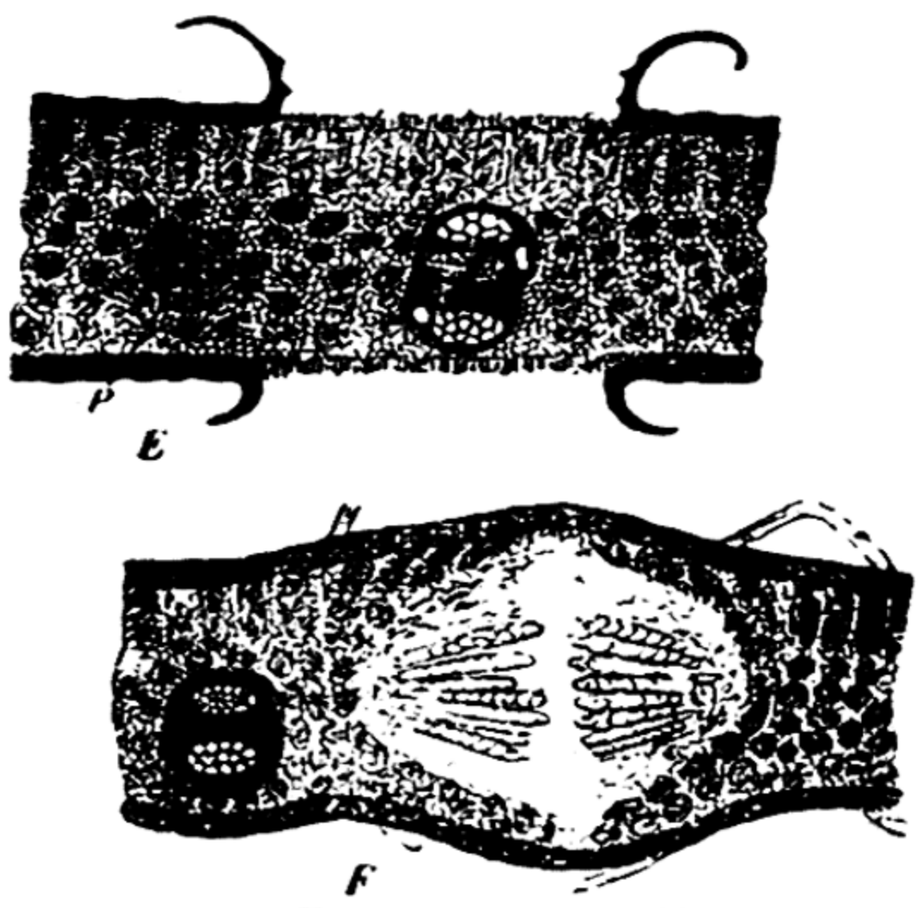


FIG. 154.—D. onobrychidis. *E*, conidial stage; *F*, ascocarp and asci. After Müller.

Plowrightia Saccardo (p. 216)

Stromata formed within the tissues of the host plant, erumpent, tubercular or cushion-shaped, depressed or elevated, smooth, later frequently wrinkled, white within; asci cylindric, 8-spored; spores ovate, 2-celled, hyaline or light green; conidial forms Cladosporium, Dematium, etc.

Some twenty species are known. They are distinguished from Dothidia by the hyaline spores.

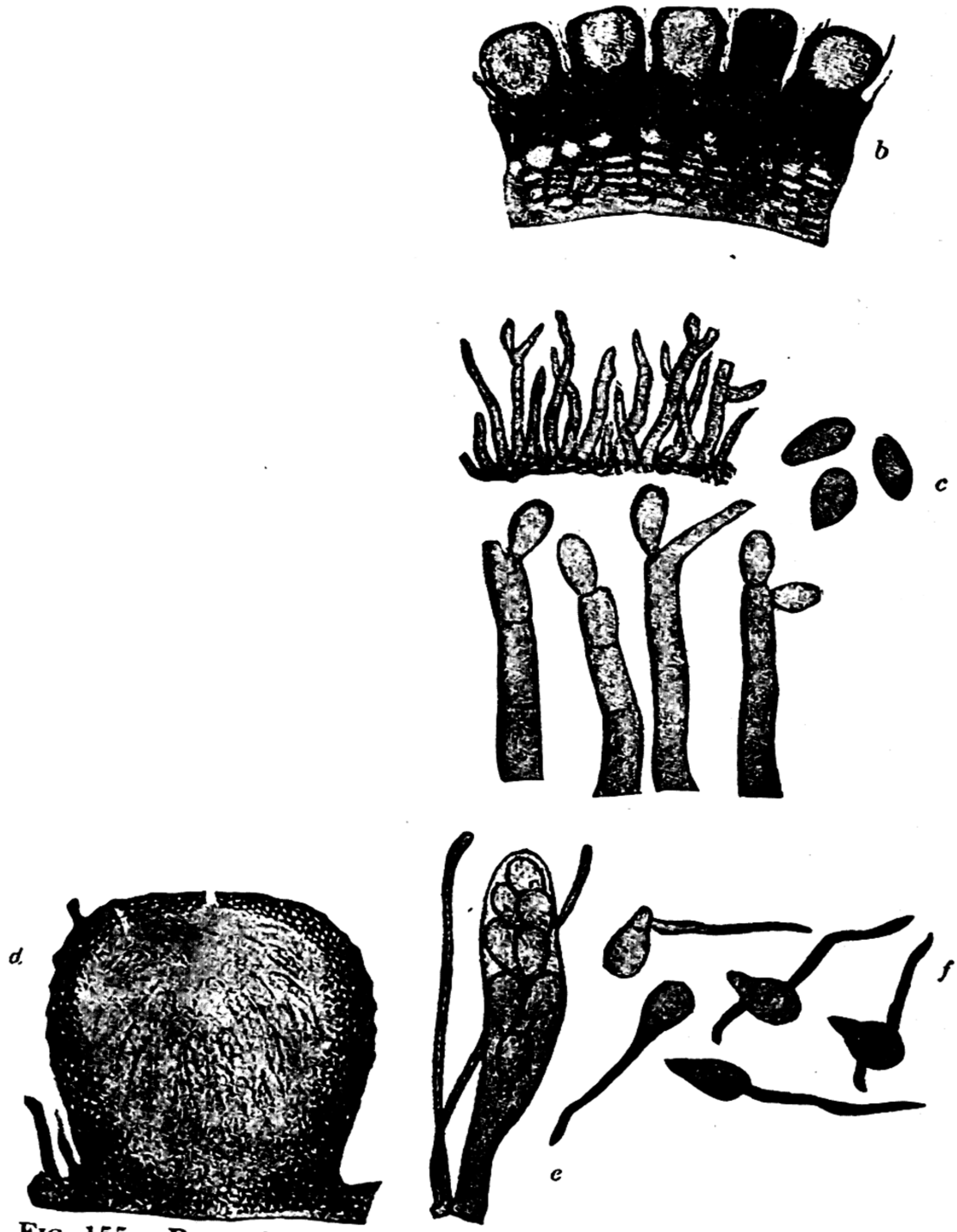


FIG. 155.—P. morbosa. *b*, magnified section of a knot showing the perithecia; *c*, conidiophores and conidia; *d*, section of a perithecium showing numerous asci, one of which is shown more highly magnified at *e*; *f*, several of the two-celled ascospores germinating in water. After Longyear.

P. morbosa (Schw.) Sacc.[153-157, 266]

Stromata elongate, cushion-shaped, rarely tubercular, up to 2 or

3 dm. long; perithecia scattered, often entirely suppressed; asci about 120 μ long; spores variously arranged in the ascus, 16–20 x 8–10 μ, ovate, the cells usually unequal; paraphyses filiform.

Conidia (= Cladosporium sp.) produced upon greenish areas on the young stromata; conidiophores erect, flexuose, septate, simple, 40–60 x 4–5 μ; conidia borne singly at the apex of the conidiophore, obovate, unicellular, light brown, about 6–8 x 2–5 μ.



FIG. 156.—P. morbosa; host showing opportunity for lodgement for spores in a crotch. After Lodeman.

Hosts: Cultivated sour cherry and plum, wild red and yellow plum, Chickasaw plum, choke cherry, wild red cherry and wild black cherry. Found only in America.

The mycelium invades the cambium of twigs and from it grows outward into the bark region causing the bark elements to overgrow and the twig to swell slightly during the first summer. With the renewed growth of the following spring the swelling proceeds rapidly. During May to June the mycelium ruptures the bark which is soon lost and a dense fungous pseudoparenchyma is formed. From this the conidiophores appear, forming a velvety growth of olivaceous color. At this period the knot consists largely of a fungous stroma with an admixture of bark elements and even some wood cells.

Later in the season conidiophores cease to form and the knot turns to a black hard stroma. Perithecia now become easily visible in this black stroma and in January or later the asci mature. Farlow has described "stylospores" (a form named Hendersonula morbosa by Saccardo the connection of which to P. morbosa is in some doubt) and spermogonia and pycnidia. Humphrey [156] from ascospores, in artificial media, raised a pycnidial form which seemed to be distinct from any of these. That the fungus is the actual cause of the black knot was first demonstrated by Farlow [154] in 1876, though the fungus was described as early as 1821 by Schweintiz.[158]

Lodeman [153] considered that infection is favored by cracks existing at crotches of the tree. Fig. 156.

P. ribesia (Pers.) Sacc. is found in Ribes twigs and
P. virgultorum (Fr.) Sacc. on birch. Both are European.
P. agaves occurs on the maguey.[293]

Dothidea Fries. distinguished from Plowrightia by its colored spores, contains some twenty-five species which occur on twigs of Sambucus, Rosa, Buxus, Betula, Juniperus, Quercus and many other woody plants.

D. rosæ Fries. is common as the supposed cause of a rose tumor.
D. noxia Ruhl. causes an oak twig disease in Germany.[159]

Phyllachora Nitschke (p. 217)

Stroma sunken, united to the parenchyma and epidermis of the host leaf, rarely erumpent, encrusted, usually jet-black; perithecia sunken in the stroma, rather numerous, with more or less distinct ostioles; asci cylindric, 8-spored; spores ellipsoid or ovate, 1-celled, hyaline or yellowish; paraphyses present.

More than two hundred species, largely tropical, are known on a wide range of hosts. All are leaf parasites.

P. graminis (Pers.) Fcl. Stromata variable in size and form, causing conspicuous black spots on leaves of the host; perithecia immersed, ostiolate; asci short-pedicillate, cylindric, 70–80 x 7–8 μ; spores obliquely uniseriate, ovoid, hyaline, 8–12 x 4–5 μ; paraphyses filiform. No conidia are known.

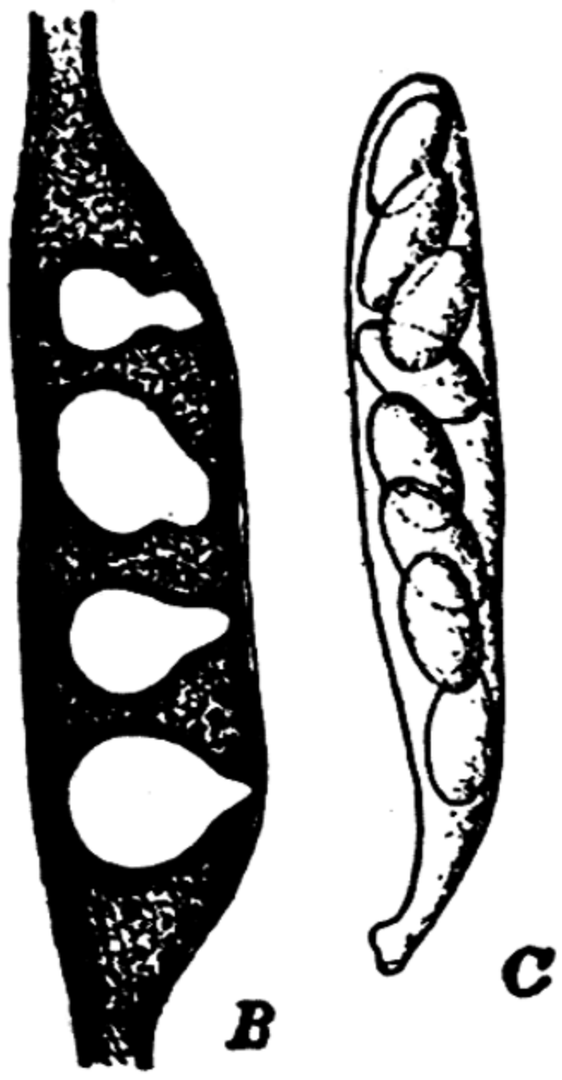


FIG. 157.—P. graminis. *B*, stroma in section; *C*, an ascus and spores. After Winter.

This fungus occurs on many grasses and sedges with slight injury to them.

P. pomigena (Schw.) Sacc. produces black spots, scarcely ever above 5 mm. in diameter, on apples, especially the Newton Pippin, in the eastern United States. Little is known of the species.

P. trifolii (Pers.) Fcl. causes small black spots 1 mm. or less in diameter on clover leaves; asci cylindric; spores uniseriate, oval, hyaline, 8–10 x 5–6 μ.

Conidia (=Polythrincium trifolii) precede the asci on the stro-

mata; conidiophores wavy or zigzag, erect, simple, black, conidia obovate, 1-septate, constricted, pale olivaceous, 20–24 x 9–10 μ.

The conidial form is very common on various species of clover in Europe and America while the ascosporic stage is mentioned only by Cooke [160] and Clevenger.[161]

P. cynodontis (Sacc.) Niess. on Cynodon, **P. poæ** (Fcl.) Sacc. on Poa and **P. dapazioides** (Desm.) Nke. on Box and Rhododendron are European.

P. makrospora Zimm. occurs on Durio zibellinus;

P. sorghi v. Höh. on Sorghum vulgare.[162]

Dothidella Spegazzini differs from Phyllachora in having 2-celled hyaline spores, the cells unequal in size. There are over fifty species of the genus. Epiphyllous, subrotund confluent, convex, grayish-black, on white spots; ostiole granular; asci cylindric, short-stipitate, 60–70 x 8 μ; spores oblong, ovate oblong, hyaline, 10–15 x 5 μ. **D. ulmi** Duv.[340] Conidia=Septoria ulmi and Piggatia astroidea. On elm in Europe and America. Other species are **D. thoracella** (Rostr.) Sacc. on Sedum, in Europe, **D. betulina** (Fries) Sacc. on Betula in Europe and Asia.



FIG. 158.—D. betulina. Asci and spores. After Winter.

Sphæriales (p. 124)

Mycelium chiefly confined to the substratum; perithecia variable, usually globose, with a more or less elongated ostiole, hairy or smooth, free on the substratum, more or less deeply sunken, or borne on or sunken in a stroma; asci borne basally, variable in size, opening by a pore; spores variable, globose, ovate to elongate or filiform, hyaline or colored; paraphyses usually present; conidial forms various.

The stromata may vary from a delicate hyphal weft to a firm crustaceous structure. The pycnidia are mostly carbonous, black and brittle. Conidia of many forms are present and often constitute the only truly parasitic form of the fungus; the ascigerous form developing only after the death of the part of the host involved.

The order is very large, embracing according to Engler & Prantl some eighteen families and over six thousand species.

Key to Families of Sphæriales

Perithecia free, either without a stroma, partly seated in a loose mass of mycelium, or sessile above an imperfect stroma
- Walls of the perithecia thin and membranous; asci soon disappearing
  - Perithecia always superficial, with copious tufts of hair at the mouth — 1. **Chætomiaceæ.**
  - Perithecia usually sunken, with only short hairs about the mouth..... — 2. **Sordariaceæ,** p. 224.
- Walls of the perithecia coriaceous or carbonous
  - Perithecia either entirely free, or with the base slightly sunken in the substratum or stromatic layer
    - Stroma wanting or only thread-like or tomentose
      - Mouths of the perithecia mostly in the form of short papillæ..... — 3. **Sphæriaceæ,** p. 225.
      - Mouths of the perithecia more or less elongate, often hair-like.. — 4. **Ceratostomataceæ,** p. 232.
    - Stroma present
      - Stromata mostly well developed, indefinite; perithecia in close irregular masses, never flask-like of funnel-like at the apex — 5. **Cucurbitariaceæ,** p. 234.
      - Stromata small, sharp-bordered; perithecia in rows or in regular rounded masses, flask-shaped with funnel-shaped mouths..... — 6. **Coryneliaceæ.**
  - Perithecia more or less deeply sunken in the substratum at base, free above
    - Mouths of the perithecia circular in outline..... — 7. **Amphisphæriaceæ.**

Mouths of the perithecia laterally compressed. . . . . 8. **Lophiostomataceæ.**

Perithecia without a stroma, and sunken in the substratum, or with a stroma

Stromata none; perithecia rarely united above by a black tissue (clypeus)

Asci not thickened at the apex, mostly projecting at maturity

Walls of the perithecium thin, coriaceous; mouth mostly short or plane

Asci clinging together in fascicles, without paraphyses. . . . . [p. 235. 9. **Mycosphærellaceæ,**

Asci not fasciculate; with paraphyses. . . . . 10. **Pleosporaceæ,** p. 250.

Walls of the perithecia carbonous or thick coriaceous; spores large, mostly enveloped by gelatine. . 11. **Massariaceæ,** p. 262.

Asci usually thickened apically, opening by a pore; perithecia usually beaked

Perithecia without a clypeus. . . . . 12. **Gnomoniaceæ,** p. 263.

Perithecia with a clypeus. . . . . 13. **Clypeosphæriaceæ,** p. 276.

Perithecia firmly imbedded in a stroma, the mouths only projecting, or becoming free by the breaking away of the outer stromatic layers

Stromata fused with the substratum

Conidia produced in pycnidia. . . . . 14. **Valsaceæ,** p. 277.

Conidia developed from a flattened surface. . . . . 15. **Melanconidaceæ,** p. 279.

Stromata formed almost wholly of hardened fungal hyphæ

Spores small, cylindric, 1-celled, mostly curved, hyaline or yellowish-brown. . . . . 16. **Diatrypaceæ,** p. 281.

Spores rather large, 1 to many-celled, hyaline or brown, conidia mostly in cavities in the stroma. . . . . 17. **Melogrammataceæ,** p. 282.

Spores 1-celled, rarely 2-celled, blackish-brown. Conidia devel-

oped on the upper surface of the young stroma..... 18. **Xylariaceæ, p. 284.**

Families Nos. 1, 6, 7, 8, 17 are saprophytes on plants and animals.

Sordariaceæ (p. 222)

Perithecia superficial or deeply sunken in the substratum, often erumpent at maturity, thin and membranous to coriaceous, slightly transparent to black and opaque; stroma usually absent, if present the perithecia immersed in it with projecting papilliform beaks; asci usually very delicate, cylindric, 8-spored; spores usually dark-colored; paraphyses abundant.

A small order, chiefly dung inhabiting.

Key to Genera of Sordariaceæ

Spores continuous
  Without a stroma
    Neck of the perithecium hairy..... 1. **Sordaria.**
    Neck of the perithecium with black spines..... 2. **Acanthorhynchus, p. 224.**
  With a stroma..... 3. **Hypocopra.**
Spores 2 or more celled
  Spores 2-celled
    Spores hyaline..... 4. **Bovilla.**
    Spores dark-brown..... 5. **Delitschia.**
  Spores 4 to many-celled
    Stroma absent..... 6. **Sporormia.**
    Stroma present..... 7. **Sporormiella.**
  Spores muriform; stroma present..... 8. **Pleophragmia.**

Acanthorhynchus Shear [163]

Perithecia scattered, submembranous, buried, beaked, the beak with non-septate spines; asci opening by an apical pore; paraphyses present, septate; spores continuous, brownish-yellow.

There is a single species, A. vaccinii Sh.[163]

Amphigenous: perithecia subglobose to flask-shaped, scarcely erumpent, 120–200 μ in diameter, neck stout, exserted, $^1/_3$–$^1/_2$ the length of the perithecium; spines 50–70 x 8–9 μ; asci subelliptic to somewhat clavate, subsessile, 120–155 x 24–44 μ; spores oblong-

elliptic, surrounded by a mucilaginous layer, 24–32 x 12–18 μ; paraphyses exceeding the asci.

The mycelium produces rot of cranberries, also leaf spots, but the fructification of the fungus is rarely found in nature except on

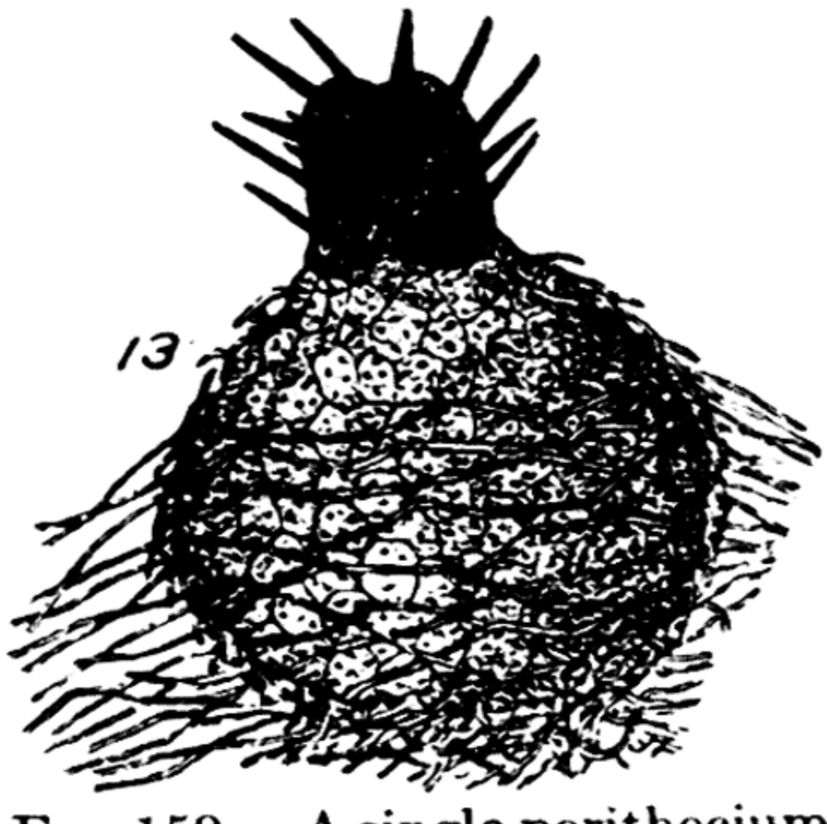


FIG. 159.—A single perithecium of A. vaccinii taken from a pure culture on corn meal. After Shear.



FIG. 160.—Acanthorhynchus; a germinating ascospore bearing the peculiar appressorium, 17, view from above. After Shear.

old fallen leaves. In culture, however, it produces abundant perithecia. When on the leaf the perithecia are subepidermal and are sparsely scattered over the lower surface. No conidial or pycnidial form is known. Remarkable appressoria are produced by the germ tubes from the spores, Fig. 160.

Sphæriaceæ (p. 222)

Perithecia single or clustered, free or with a false stroma in which they are more or less sunken; walls leathery, horny or woody; ostiole rarely elongate, usually papillate; spores frequently appendaged.

The family is distinguished by its free perithecia with papillate ostioles. It contains about seven hundred species.

KEY TO GENERA OF Sphæriaceæ

Perithecia hairy above, rarely smooth above and hairy beneath
  Spores 1 or 2-celled
    Perithecia thin, cuticulate or leathery
      Spores 1-celled; asci apically thickened. ..... 1. **Niesslia.**

Spores 2-celled; asci not apically thickened. . . . . 2. **Coleroa,** p. 227.
Perithecia thick, leathery or carbonous
Spores hyaline, sometimes becoming brown, 1 or 2-celled
Spores ellipsoid. . . . . 3. **Trichosphæria,** p. 228.
Spores cylindric, bent. . . . . 4. **Leptospora.**
Spores dark colored, 2-celled. . . . . 5. **Neopeckia.**
Spores more than 2-celled
Perithecia thin, leathery or cuticularized. . . . . 6. **Acanthostigma,** p. 229.
Perithecia thick, carbonous or woody
Spores 4-celled, the two middle cells brown, the end cells hyaline. . . . 7. **Chætosphæria.**
Spores many-celled, concolorous, hyaline or brown
Spores spindle-form. . . . . 8. **Herpotrichia,** p. 229.
Spores elongate-cylindric. . . . . 9. **Lasiosphæria.**
Perithecia smooth
Perithecia tuberculate or irregularly thickened
Spores ellipsoid, 2 to many-celled, hyaline. . . . . 10. **Bertia.**
Spores spindle-form, 4 to 11-celled, hyaline. . . . . 11. **Stuartella.**
Spores muriform, dark. . . . . 12. **Crotonocarpia.**
Perithecia not tuberculate
Spores 1-celled, dark
Spores with hyaline appendages on each end; perithecia thick, leathery. . . . . 13. **Bombardia.**
Spores unappendaged, perithecia carbonous . . . . . 14. **Rosellinia,** p. 230.
Spores 2 to many-celled
Perithecia thin, leathery; spores 2-celled. . . . . 15. **Lizonia.**
Perithecia thick, leathery or carbonous, brittle
Spores ellipsoid
Spores 2-celled

Spores hyaline, sometimes becoming brown	16. **Melanopsamma.**
Spores hyaline to green	17. **Thaxteria.**
Spores dark-colored	18. **Sorothelia.**
Spores 3 to many-celled	
Spores hyaline	19. **Zignoëlla.**
Spores dark-colored	20. **Melanomma.**
Spores elongate, spindle-form, hyaline, many-celled	21. **Bombardiastrum.**

Coleroa Fries (p. 226)

Perithecia free, small, globose, flask-shaped; asci 8-spored; spores

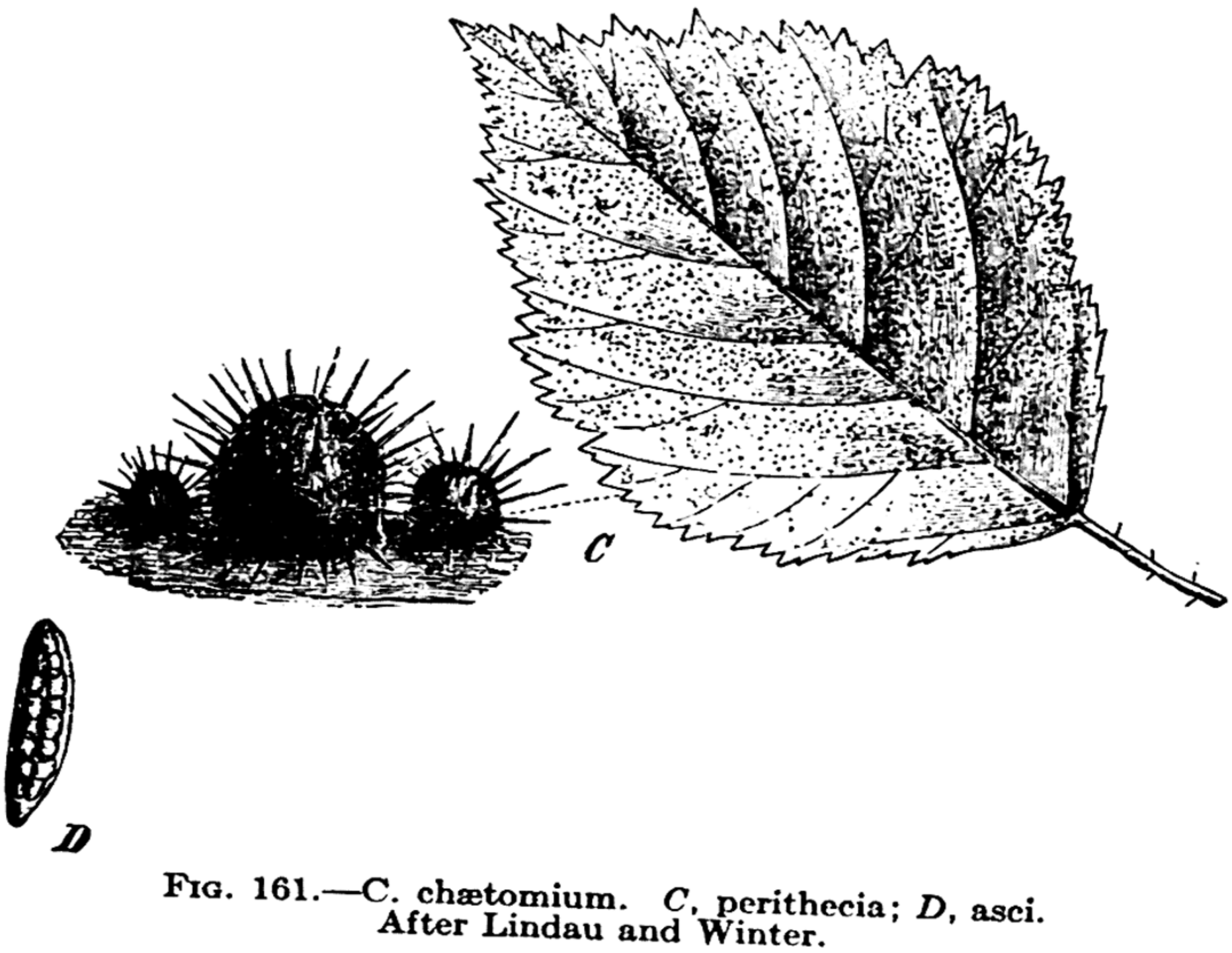


FIG. 161.—C. chætomium. *C*, perithecia; *D*, asci. After Lindau and Winter.

ovate, 2-celled, hyaline, green or golden-brown; paraphyses poorly developed.

Conidia=Exosporium.

This genus, of some thirteen species all of which are parasitic, is quite similar to Venturia. The chief economic species are **C. chætomium** (Kze.) Rab. (Conidia=Exosporium rubinus) on Rubus in Europe and **C. sacchari** v. B. d H., on sugar cane in Java.[164]

Trichosphæria Fuckel (p. 226)

Perithecia usually free, globose, woody or carbonous, hairy, ostiole flat or papillate; asci-cylindric, 8-spored; spores 1 to 2-celled, hyaline; paraphyses present.

There are some forty species, mainly saprophytes.

T. sacchari Mass.[165, 166]

Perithecia broadly ovate, dark-brown, beset with brown hairs; spores elongate-ellipsoid, 1-celled; the conidial forms are various

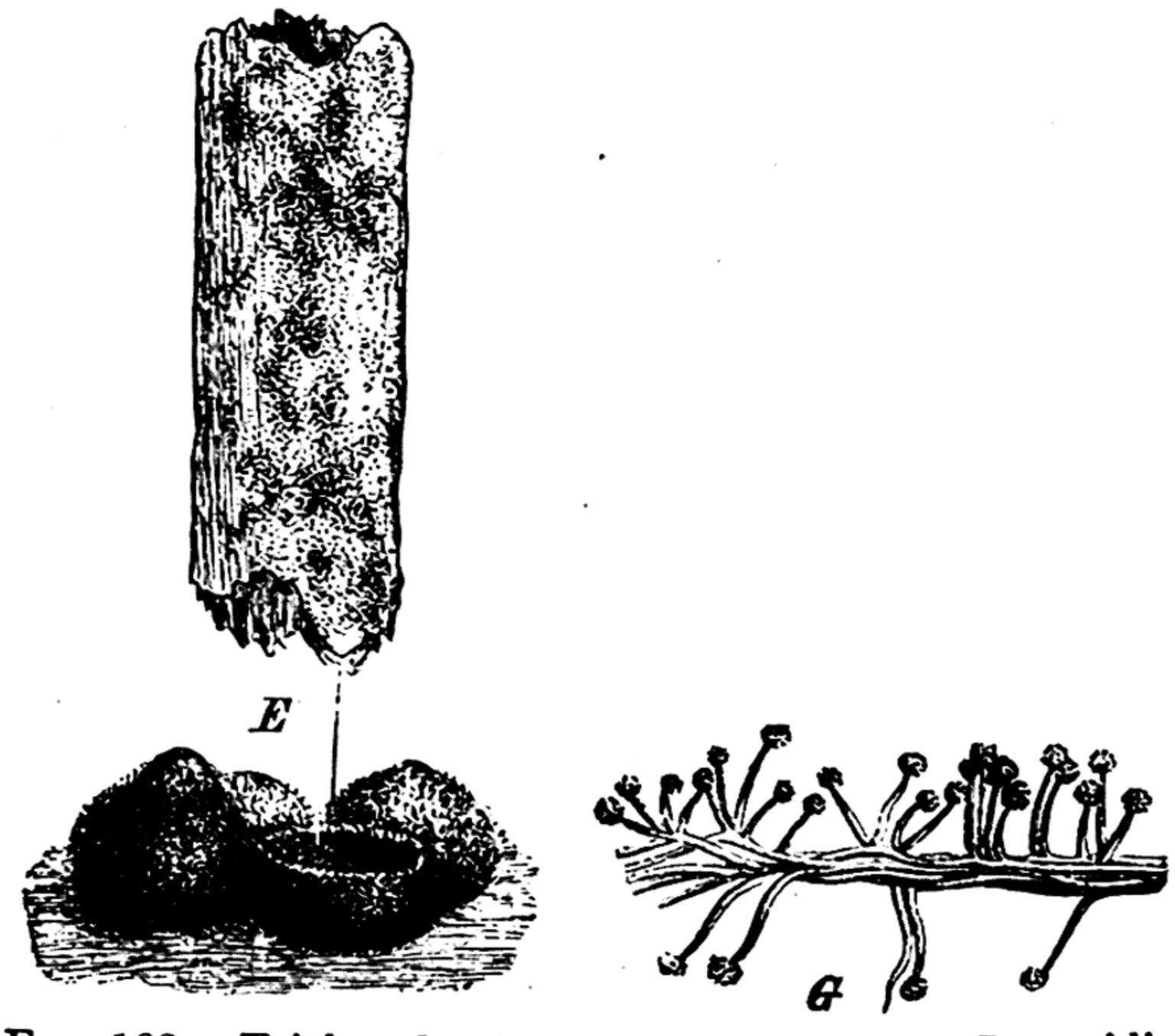


FIG. 162.—Trichosphæria. *E*, habit sketch; *G*, conidial stage. After Lindau, Winter and Brefeld.

and their genetic connection is by no means certain. (1) (=Coniothyrium megalospora) Pycnidia 1–3, on a dark-colored, parenchymatous stroma; conidia elongate, straight or curved, brownish, 12 x 5 μ, (2) The macroconidia (=Thielaviopsis ethaceticus) see p. 596, are often found forming intensely black, velvety layers lining cracks and cavities in diseased canes. (3) Microconidia produced on the surface in Oidium-like chains. Their connection with this fungus is disputed and uncertain.[349]

It is a sugar cane parasite.

Acanthostigma de Notaris (p. 226)

Perithecia free, globose or ovate, very small; walls leathery, black, beset with stiff bristles, ostiole short; asci usually cylindric, rarely ovate, 8-spored; spores spindle-shaped, multicellular by cross walls, hyaline; paraphyses few or none.

There are some thirty species, mostly saprophytes.

A. parasiticum (Hart.) Sacc.[167-168]

Perithecia globose, minute, with rigid divergent hairs, 0.1–0.25 mm. in diameter; asci 50 μ long, early disappearing; spores fusoid, straight or curved, smoky, 15–20 μ, continuous or 2 to 3-septate.

Common on leaves of Abies, Tsuga and other conifers in Europe and America. The hyaline mycelium grows on the lower sides of branches and onto the leaves killing them and matting them to the branches. The mycelial cushions later turn brownish and eventually very small perithecia form on them.

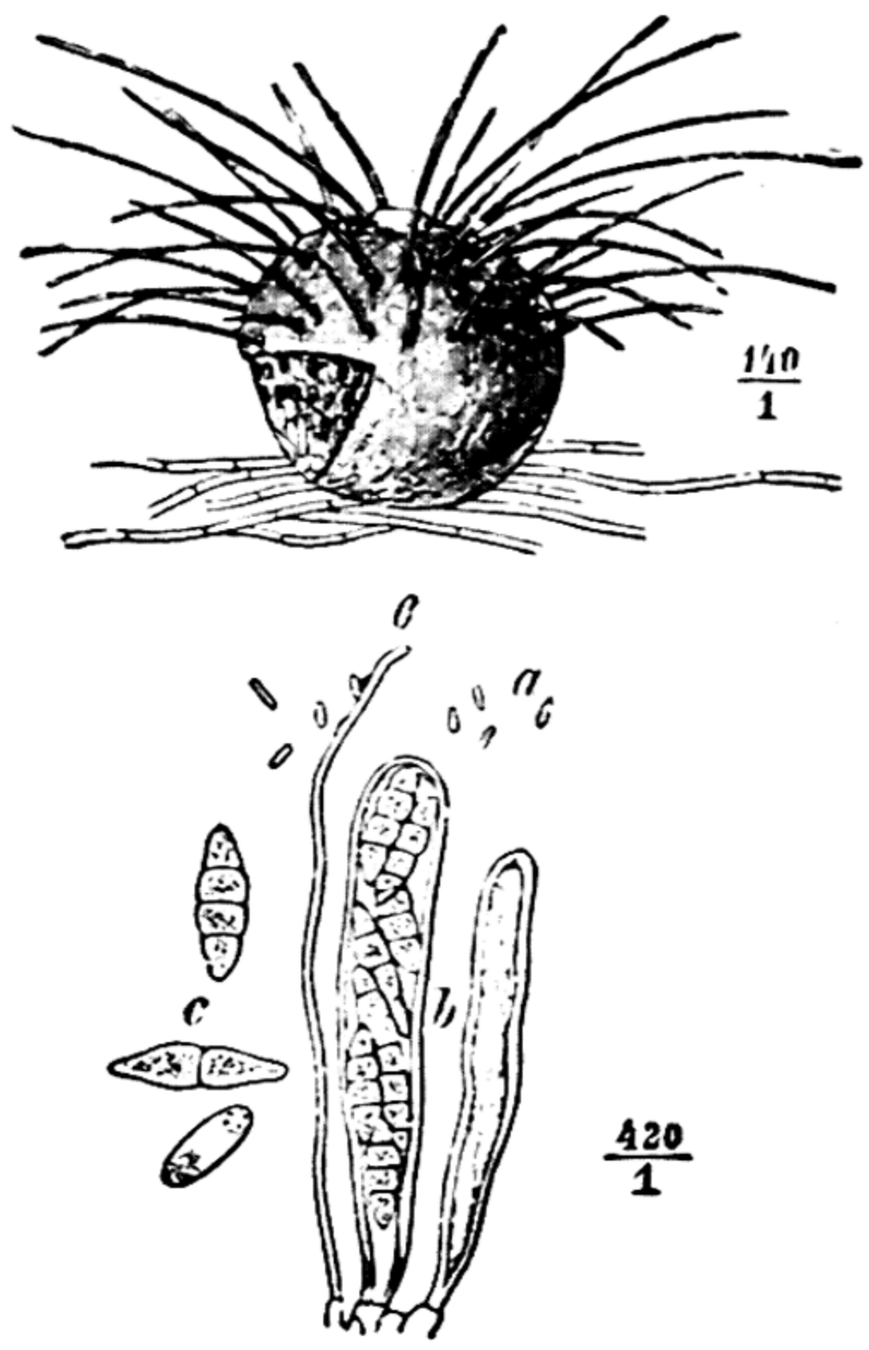


FIG. 163.—Perithecium of A. Trichosphæria parasiticum, showing ostiole, bristles, asci, paraphyses and spores. After Hartig.

Herpotrichia Fuckel (p. 226)

Perithecia superficial, globose or subglobose, texture firm, coriaceous to subcarbonous, hairy or smooth, ostiole papillate or not; asci oblong to clavate; spores fusiform, 2 or many-celled, hyaline or brown; paraphyses none.

The species, numbering about twenty-five and growing on woody plants, are mostly saprophytes.

H. nigra Hart.[169]

Mycelium dark-brown, widely spreading, haustoria slender, lighter in color; perithecia globose, dark, 0.3 mm. in diameter; asci elongate, 76–100 x 12 μ; spores constricted, 1–3 septate.

Common in Europe on branches of Larix, Abies, Juniperus, spruce and pine, doing great damage. The dark-brown mycelium grows over the plant, killing and matting the leaves.

Rosellinia Cesati & de Notaris (p. 226)

Perithecia superficial, but often with the bases more or less sunken in the substratum, coriaceous or carbonous; brittle, spherical or ovate, bristly or not; asci cylindric, 8-spored; spores elliptic, oblong or fusiform, 1-celled, brown or black; paraphyses fusiform. Conidia of the type of Coremium, Sporotrichum, etc.



FIG. 164. — Herpotrichia. *B*, ascus; *C*, spore. After Winter.

In most cases the active parasitic stage occurs on roots and consists of a vigorous white mycelium, which remains for a long time sterile, developing large branching and interlacing rhizomorphs (Dematophora) which later become brown. These resemble somewhat, but are distinguishable from, the rhizomorphs of Armillaria mellea; again, they are Rhizoctonia-like.

There are over one hundred seventy species, mostly saprophytic.

R. necatrix (Hart.) Berl.[170, 171]

A destructive fungus, long known as Dematophora necatrix, possesses a white mycelium which invades the small roots, thence passes to larger ones, extending in trees through the cambium and wood to the trunk, occasionally rupturing the bark and producing white floccose tufts. Sclerotia of one or more kinds are produced in the bark and often give rise to conidia on tufted conidiophores in a Coremium-like layer (Fig. 165). The mycelium, when old, turns brown and produces large branching, interlacing rhizomophic strands which spread to the soil, or wind about the roots.

In some instances the connection of the ascigerous with the sterile or conidial stages is well established; in others the asci have been found but rarely and the evidence of genetic connection is not complete. It is probable that some fungi reported as Dematophora do not in reality belong to Rosellinia.

The fungus attacks nearly all kinds of plants.

Perithecia were found by Viala [172] and by Prillieux [173] on old wood, long dead from such attack. These belong to the genus Rosellinia and are believed to present the ascigerous form of Dematophora necatrix. Similar claims of relationship of this fungus to several other genera have been made and its actual position cannot be considered as established with certainty.

R. massinkii Sacc.

Perithecia sparse, globose or depressed, carbonous, 165 μ; asci cylindric, 54 x 8 μ; spores dark-brown, elliptic, 1-rowed, 10 x 5 μ.

It is reported by Halsted on hyacinth bulbs.

R. bothrina B. & Br. is the cause of a tea root disease.

Pseudodematophora closely allied to the above forms is described by Behrens [174] on diseased grape roots.

R. quercina Hart. is parasitic on roots and stems of young oaks, producing a Rhizoctonia-like mycelium, at first white, later brown. Perithecia are usually abundant. Black sclerotia the size of a pin head are also present superficially.



FIG. 165.—R. necatrix. *4*, coremium and conidia; *5*, perithecia extruding spores; *6*, asci and paraphyses. After Hartig, Prillieux and Viala.

R. radiciperda Mas. closely allied to R. necatrix, affects a large number of hosts, among them apple, pear, peach, cabbage, and potato.

An undetermined species of this genus is said to cause a cranberry disease.[175] Shear, however, in his extensive studies of cranberry diseases, did not find it.

R. aquila (Fr.) d. Not. injures Morus. Its conidial form is

Sporotrichum fuscum. **R. ligniaria** (Grev.) Nke. occurs on ash trees. **R. echinata** Mas. is reported on "all kinds of Dicotyledonous shrubs and herbs." [22]

Melonomma Fcl. in the species **M. henriquesianum** Bros. & Roum. is parasitic on cacao stems.

M. glumarum Miy. is on rice.[305]

Ceratostomataceæ (p. 222)

The fungi of this family are very similar to the Sphæriaceæ, but are distinguished by less pronouncedly carbonous perithecia which may be merely membranous, and open by an elongate, beak-like ostiole. It is a family of only about one hundred twenty-five species, chiefly saprophytes.

Key to Genera of Ceratostomataceæ

Spores 1-celled	
Spores hyaline	1. **Ceratostomella,** p. 232.
Spores brown	2. **Ceratostoma.**
Spores 2-celled	
Spores hyaline	3. **Lentomita.**
Spores dark-colored	
Perithecia on a cottony stroma	4. **Rhynchomeliola.**
Perithecia not on a cottony stroma	5. **Rhynchostoma.**
Spores many-celled	
Spores with cross walls only	
Spores elongate, 4 to many-celled, hyaline or brown	6. **Ceratosphæria.**
Spores filiform, many-celled, usually hyaline	
Perithecia erect, astromatic	7. **Ophioceras.**
Perithecia horizontal in stromatic nodules	8. **Cyanospora,** p. 233.
Spores muriform	9. **Rhamphoria.**

Ceratostomella Saccardo

Perithecia superficial, firm; asci ovate, 8-spored, disappearing early; spores elongate, blunt or pointed, 1-celled, hyaline. About thirty species. An extensive study of the genus was made by

Hedgcock [177] who recognizes several species as discoloring lumber.

C. pilifera (Fr.) Wint.[13] has been described in detail by von Schrenk as the cause of a blue color in pine wood.[176]

Cyanospora Heald & Wolf (p. 232)

Perithecia solitary or in clusters of two or three on stromatic nodules, immersed, horizontal; ostiole lateral, neck short; asci

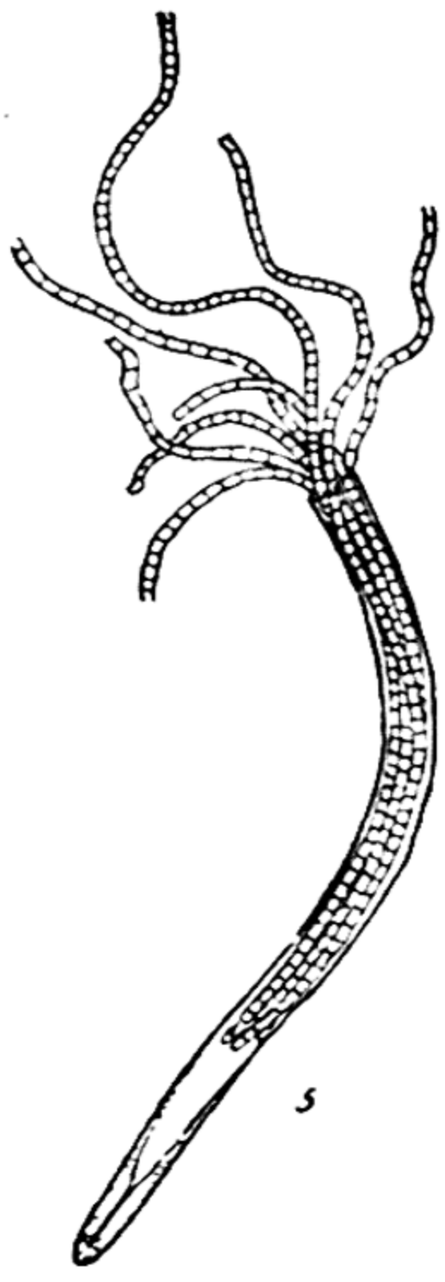




FIG. 166.—C. pilifera perithecium, asci and spores. After von Schrenk.

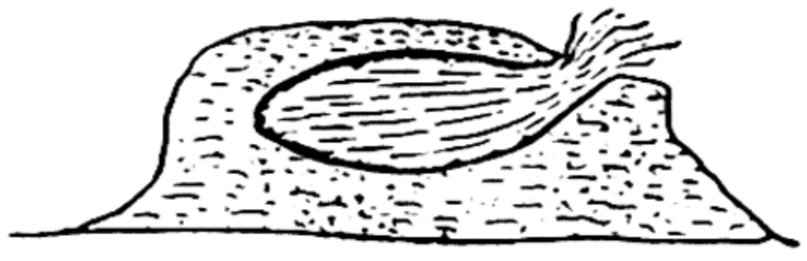


FIG. 167.—C. albicedræ. Section of a perithecium in its stroma. After Heald and Wolf.

FIG. 168.—C. albicedræ. Upper part of an ascus showing thickened apical wall and coiled spores. After Heald and Wolf.

slender, linear, surrounded by a gelatinous matrix, apically thickened; spores filiform, multiseptate, hyaline.

A single species.

C. albicedræ Heald & Wolf.

Stroma on bark or wood of the host, varying from gray on the bark to black on wood, lenticular, 1–2 mm. long, solitary or clustered; perithecia 825–1200 x 260–400 μ; asci 700–1100 x 8–10 μ; spores 600–1000 x 3 μ; paraphyses numerous, continuous, 1 μ in diameter.

The fungus is described in detail by Heald and Wolf [178] as caus-

ing whitening of the mountain cedar (Sabina sabinoides) from Texas to Central Mexico. The seat of infection is the younger twigs and the young trees, especially where in shade. The disease may kill the entire trees.

Cucurbitariaceæ (p. 222)

Perithecia clustered, immersed at first, then erumpent, seated on a stroma, leathery to carbonous; paraphyses present. The species numbering about one hundred fifty are mostly saprophytes.

Key to Genera of Cucurbitariaceæ

Spores 1-celled
  Asci 8-spored
    Spores large, green. ..... 1. **Bizzozeria.**
    Spores small, hyaline. ..... 2. **Nitschkia.**
  Asci many-spored. ..... 3. **Fracchiæa.**
Spores 2 or more-celled
  Spores 2-celled
    Perithecia bristly, spore walls hyaline.. 4. **Gibbera, p. 234.**
    Perithecia smooth, spore walls brown.. 5. **Otthia.**
  Spores more than 2-celled. ..... 6. **Gibberidea.**
  Spores muriform. ..... 7. **Cucurbitaria, p. 234.**

Gibbera Fries.[179]

Perithecia cespitose on a superficial, thick, Demataceous, conidia-bearing, carbonous, fragile, bristly stroma; ostiole papillate; asci cylindric, 8-spored; spores oblong, elliptic, hyaline, uniseriate.

The genus contains some half dozen species, one of which **G. vaccinii** (Sow.) Fr. occurs on Vaccinium in Europe. The conidial form is Helminthosporium vaccinii. **Fig. 169.**

Cucurbitaria Gray

Perithecia cespitose or more rarely gregarious on a crustaceous stroma covered by Demataceous hyphæ, spherical, glabrous, black, coriaceous; asci cylindric, 8-spored; spores uniseriate, oblong or elliptic, muriform, brownish, paraphyses present.

Over seventy species, several of which are parasitic but none of importance in America.

C. laburni Pers. is on branches of Cytisus;

C. sorbi Karst on Sorbus twigs;

C. pityophila (Kze.) d Not. on various conifer twigs;

C. berberidis (Pers.) Gray on Berberis;

C. elongata (Fr.) Grev. on Robinia;

C. piceæ Brothwick, on Picea.

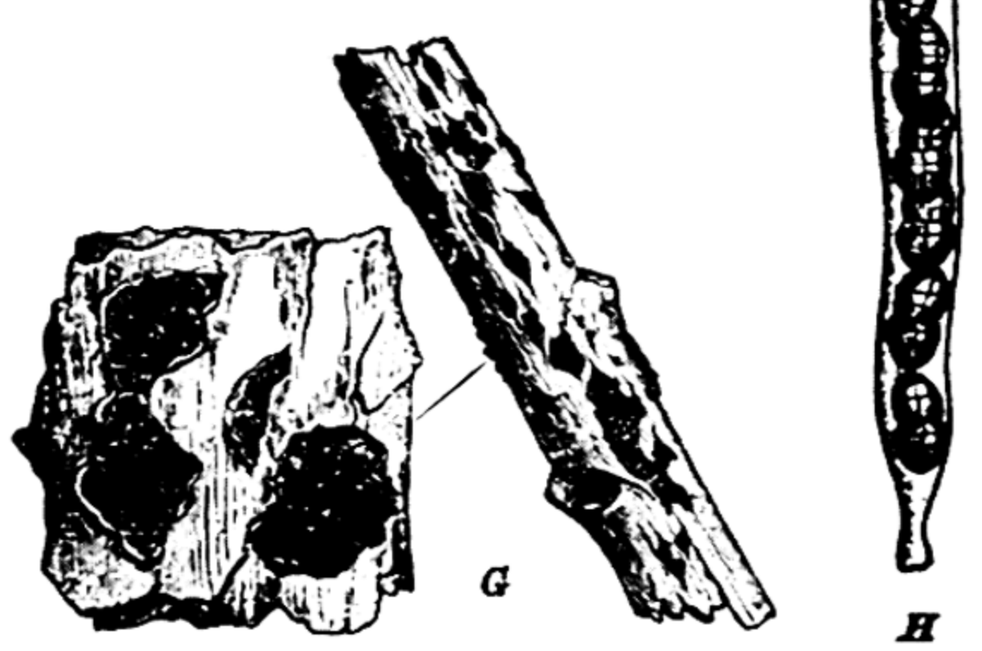
Mycosphærellaceæ (p. 223)

Perithecia mostly subepidermal, rarely subcuticular, finally more or less erumpent or even superficial, membranous or leathery,



D

FIG. 169.—Gibbera vaccinii. An ascus. After Winter.



G H

FIG. 170.—Cucurbitaria berberidis. *G*, habit sketch; *H*, ascus. After Lindau and Winter.

fragile; asci fasciculate, 8-spored; spores variable, septate, rarely muriform, hyaline to dark-brown; paraphyses none.

This family of over seven hundred species contains many saprophytes and several very important parasites.

KEY TO GENERA OF **Mycosphærellaceæ**

Spores 1 to 2-celled
- Spores hyaline or green
  - Spores 1-celled or not clearly 2-celled
    - Perithecia very small, on a basal growth of thick branched hyphæ — 1. **Ascospora,** p. 236.

Perithecia without such a basal growth
Spores typically 1-celled..... 2. **Massalongiella.**
Spores usually unequally 2-celled. 3. **Guignardia,** p. 237.
Spores 2-celled
Perithecia produced on living plants..... 4. **Stigmatea,** p. 243.
Perithecia appearing after the death of the host..... 5. **Mycosphærella,** p. 243.
Spores dark-colored
Spores 1-celled..... 6. **Müllerella.**
Spores 2-celled
Lichen-inhabiting..... 7. **Tichothecium.**
Not lichen-inhabiting..... 8. **Phæosphærella.**
Spores several-celled, hyaline
Spores elongate, with cross walls only
Spores 2 to 4-celled; on lichens..... 9. **Pharcidia,** p. 250.
Spores 4-celled; with a cottony subiculum..... 10. **Sydowia.**
Spores many-celled..... 11. **Sphærulina,** p. 250.
Spores muriform..... 12. **Pleosphærulina,** p. 250.

Ascospora Fries (p. 235)

Perithecia borne on a subiculum of thick, brown, much-branched hyphæ, globoid, black, carbonous; asci clavate, clustered, 8-spored, small; spores 1-celled, hyaline; paraphyses none.



FIG. 171.—Ascospora himantia. Asci. After Winter.

About half a dozen species, one of which is said by Vuillemin [180] to be the ascigerous form of Coryneum beyerinckii, a wound parasite common on drupaceous trees causing gummosis. Cultural evidence of this relationship is lacking, but his hypothesis may be tentatively assumed.

A. beyerinckii Vuil. Perithecia black, depressed-globose, apapillate; ostiole indistinct or absent, 100–130 μ in diameter; spores elliptic-fusoid, ends obtuse, continuous, hyaline, guttulate, 15 x 5–7 μ.

Conidia, 1. (=Phyllosticta beyerinckii) pycnidia globoid with hyaline spores.

Conidia, 2. (=Coryneum beyerinckii) conidiophores short, crowded, from a minute subepidermal stroma; conidia single, elliptic-oblong, 1 to 5-septate, brown, about 36 x 15 μ. On drupaceous hosts.

In spots on the bark the mycelium is often sterile, but when it becomes old distinct pustules usually show in a well developed subepidermal stromatic tissue and from these pustules, as they rupture the epidermis, the conidiophores are produced. Conidia usually abound on the surface of twigs which have borne affected leaves. They germinate readily and produce either a sooty super-

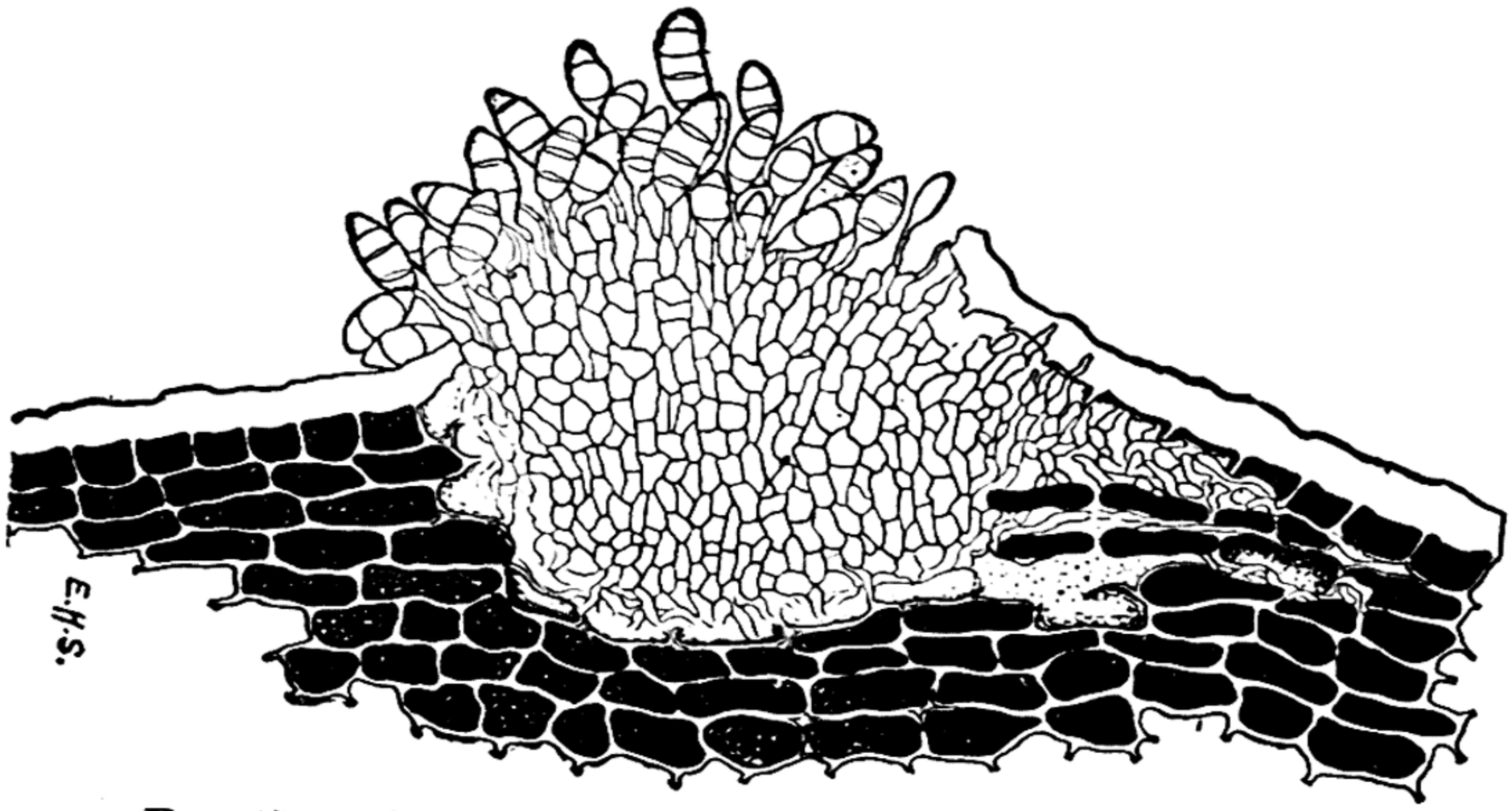


FIG. 172.—Section through a Coryneum pustule on peach. After Smith.

ficial mold or if on new bark enter the host tissue and induce spotting.

The conidial stage (Coryneum) of the fungus was grown in artificial culture by Smith [181] but no ascigerous stage corresponding with that of Vuillemin was found.

A. geographicum (D. C.) Desm. is common on leaves of pome fruits and **A. padi** Grev. defoliates cherries in Europe.

Guignardia Viala & Ravaz (p. 236)

Perithecia sunken, globoid or flattened, black, leathery; ostiole flattened or papillate; asci clavate, 8-spored; spores ellipsoid or fusiform, hyaline, somewhat arched, 1 or 2-celled; paraphyses none.

Over one hundred thirty species are known. Some are important parasites.

Conidial forms are found in Phoma and Phyllosticta.

G. bidwellii (E.) V. & R.[63, 182-192]

Perithecia minute, globose, subepidermal, erumpent, perforate; asci clavate-cylindric, obtuse, 60–70 x 10–13 μ; spores elliptic to oblong, continuous, 12–17 x 4¼–5 μ.

Conidia (=Phoma uvicola, Phyllosticta labruscæ, Næmospora ampelicida) borne in pycnidia 180 x 180 μ, subepidermal, elliptic,

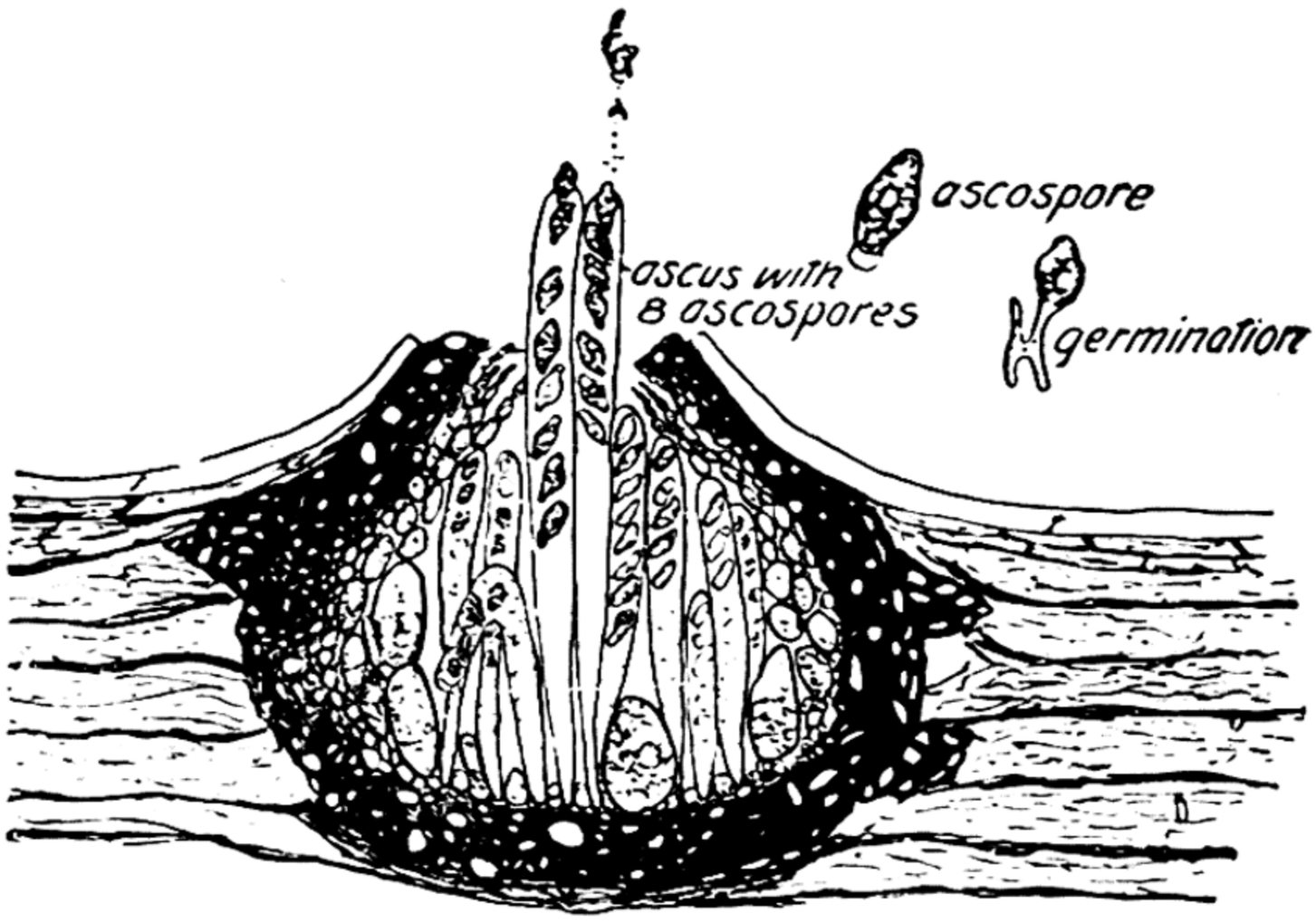


FIG. 173.—Diagrammatic section of a perithecium containing ascospores. Germination of a spore at the right. After Reddick.

thick-walled; conidiophores short, simple; conidia ovate to elliptic, 8–10 x 7–8 μ. Filiform microconidia ("spermatia") are borne in flask-shaped pycnidia 0.1–0.2 x 0.45–0.46 μ.

The fungus has been placed successively in the genera Sphæria, Physalospora, Læstadia and Guignardia.

An extensive synonomy is given by E. Rose [253] who concludes that the name should be **G. ampelicida.**

It is found on all green parts of Vitis and Ampelopsis, the ascigerous stage common only on the mummified fruits.

Perithecia were first found in 1880 by Dr. Bidwell in New Jersey. They are abundant on berries, which have wintered out doors.

Reddick admirably describes the development of the spots as follows:

On the leaves the first evidence of the spot is the slight blanching of a single one of the smaller areola of the leaf. Soon the blanching extends to adjacent areolæ, and if an areola is entered it is usually entirely involved. The small veinlets form the margin of the spot so that the outline is finely crenulate. By the time the spot is .3 to .4 mm. in diameter it has a cinereous appearance. The margin, while sharply defined, is not changed in color. By the time the spot is 1 mm. in diameter, the margin appears as a black line, while the remainder of the spot is grayish-brown. A

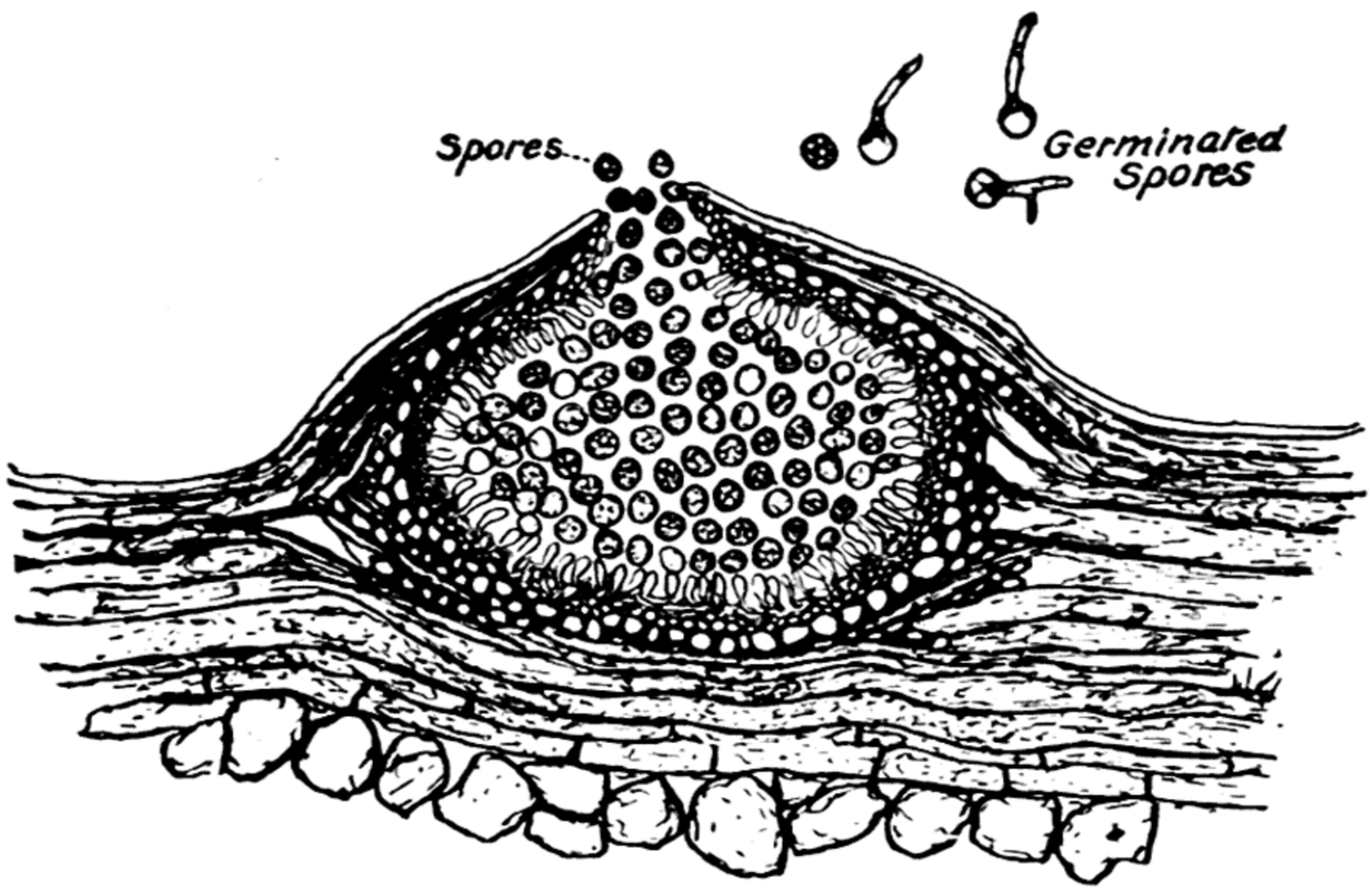


FIG. 174. Diagrammatic section through a pycnidium, showing how the spores are produced and how they germinate. After Reddick.

little later the margin is a brownish band and the brown gradually extends inward until the whole spot is covered. As soon as the brown band attains some width the blackish line on the margin is to be seen again. A second wave of deeper brown may pass across the spot but sometimes it does not get entirely across and thus leaves a marginal band of a deeper brown than the central disc. Spots vary in size from 1 mm. up to 8 mm. in diameter, but in general are 3 to 5 mm. or larger. Occasionally the whole leaf is destroyed but this is by the coalescence of many spots. When the spot has attained full size pycnidia protrude from under the cuticle and either dot the entire surface of the spot with minute specks or are more often confined to a more or less concentric ring. The different shades of color are apparent on the under side of

the leaf on such varieties as have leaves which are smooth beneath. The pyncidia, however, have never been seen on the under side of the leaf in our varieties.

On stems, tendrils, peduncles, petioles and leaf veins the spot in its first appearance is a small darkened depression which soon becomes very black. On a cane the lesion rarely extends more than a quarter of the way round, while on a tendril or leaf petiole it may extend from half to all of the way round. On shoots, the lesions never extend so deep as to cut off the sap supply, but on petioles this occasionally happens, rarely so on peduncles, and quite commonly so on pedicels and tendrils. The first indication of Black Rot on the berry is the appearance at some point of a small circular blanched spot, scarcely 1 mm. in diameter. The blanching is so slight as to be detected only by careful observation. It rapidly becomes more apparent and has a whitish appearance, the contrast becomes more apparent by the appearance of a brownish line at the margin. The whitish center increases in size and the brownish or reddish-brown ring increases in diameter as well as in width and is quite evident when the spot is 2 mm. in diameter. When the spot is 3 mm. in diameter the ring is one-half mm. in width and enough darker to give a bird's eye effect (a light circular disc with an encircling darker band). The spot rapidly increases in size so that in twelve hours more it may be 6 to 8 mm. in diameter, and the encircling band nearly 2 mm. in width. After five hours more, the spot is 8 or 9 mm. in diameter and there begins to appear an outer darker band and an inner lighter brown one which have in some cases a much lighter line between them. The aureole is thus composed of two or three bands or rings. Eighteen hours later, the spot is 1 cm. or more in diameter, is distinctly flattened, and numerous minute brown specks appear on the

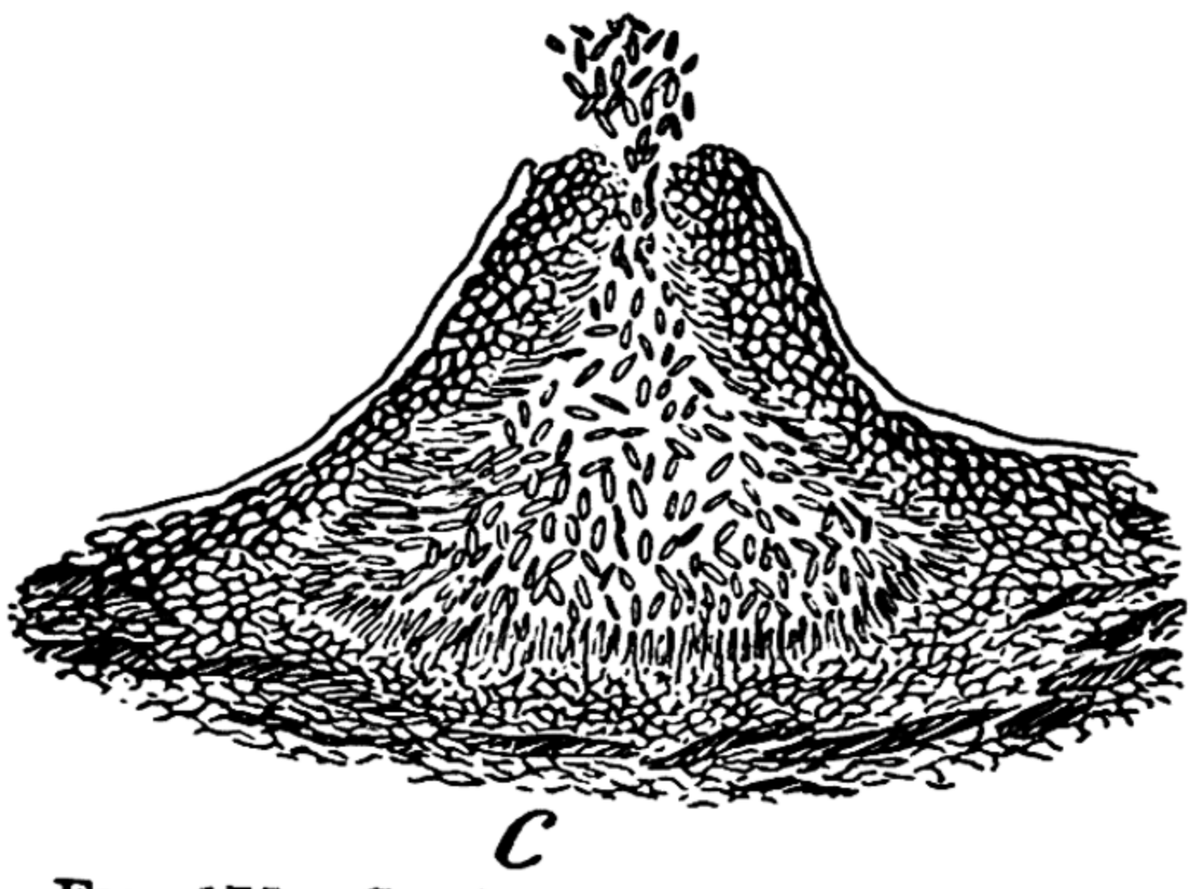


FIG. 175.—Section of a pustule showing microconidia. After Longyear.

white center of the spot. In five hours more they are so numerous as to give a blackish appearance.

In New York, Reddick found that the asci begin to ripen in May and continue to mature throughout the summer being still abundant in October. The asci swell in water often to twice the length given above; spores are forcibly ejected from the asci at maturity, being thrown to a height of 2 to 4 cm. There is at one end of the ascospore a hyaline vesicle which probably aids in fixing it to the host.[191] They germinate but slowly, requiring from thirty-six to forty-eight hours to show germ tubes. Reddick determined the incubation period on fruit as from eight to twenty-one days and found that only tender leaves still growing are susceptible. The berry is susceptible even after the calyx has fallen. The pycnidial spores are said by some to show a hyaline appendage[192] though others by careful study fail to find it.[190] These spores often live over winter.[190] The microconidia which develop in pycnidia similar to those of the macroconidia do not occur so abundantly early in the season as they do later and seem to be mainly limited to the fruits. Sporeless pycnidia, **pycnosclerotia**, also occur and may eventually develop into perithecia. Conidia on hyphæ of questionable relationship to the fungus are sometimes seen.

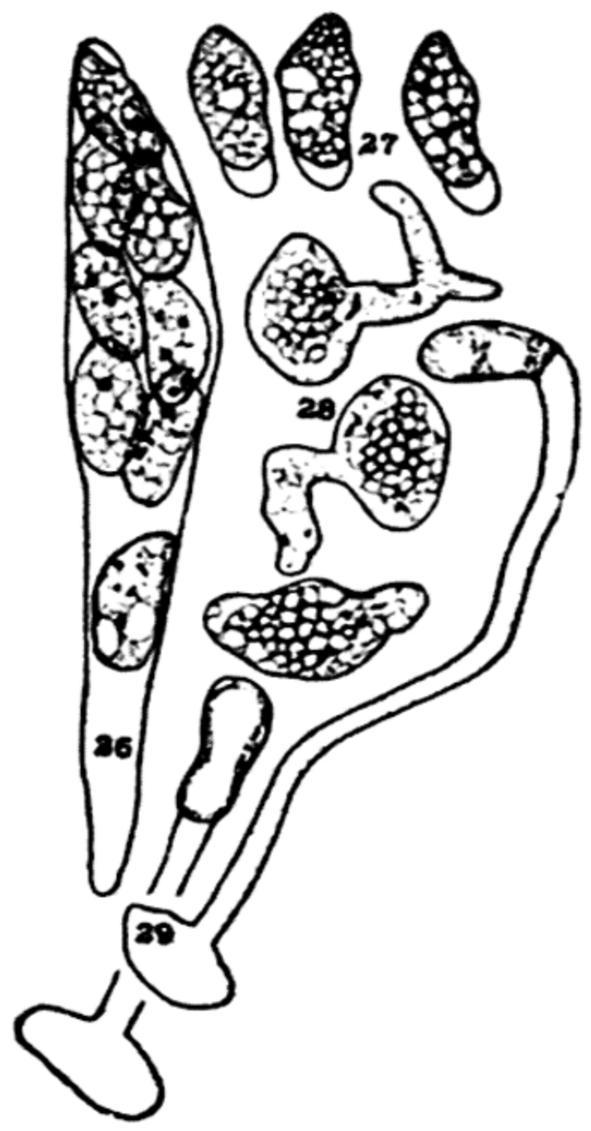


FIG. 176.—G. bidwellii; *26*, nearly mature ascus with spores; *27*, mature ascospores; *28*, germinating ascospores, *29*, same with appressoria. After Reddick.

Reddick[190] secured pure cultures in the following ways.

1. In poured plate dilution of asci; some twenty days were required.

2. By inverting a plate of sterile agar over a bunch of mature mummies floating on water. The ejected ascospores thus clung to the agar and gave pure cultures in ten days.

3. By aseptic transfer of the mycelium.

4. By aseptic transfer of pycnospores.

Artificial infections have been reported in Europe from both conidia and ascospores: Reddick, who made many thousand in-

oculations under all conceivable conditions, failed utterly of positive results.

From the Caucasus Prillieux and Delacroix [193] have described a Guignardia causing a black rot of grapes which is regarded as distinct from the usual American form, differing both in the perithecial and conidial stages. This is called **G. baccæ** (Cav.) Jacz. Its conidial form Phoma reniformis eventually covers the whole berry with pustules. Two kinds of pycnidia are described.



FIG. 177.—A vertical section of a perithecium of Guignardia vaccinii, showing asci. After Shear.

G. vaccinii Sh.[194, 195]

Perithecia on young fruit or flowers, subepidermal, globose, walls thick, carbonous; asci clavate, 60–80 μ long; spores elliptic or subrhomboidal, hyaline, becoming tinted.

Conidia (=Phyllosticta) borne in pycnidia similar to the perithecia but thinner-walled, 100–120 μ; conidia hyaline, obovoid, 10.5–13.5 x 5–6 μ. On Vaccinium.

In the decaying berries all sporing forms of the fungus are rare though in the softened tissues fungous hyphæ abound. Transferred to culture media these hyphæ grow readily and produce spores abundantly.

The conidial form is common in artificial culture; the perithetical form comparatively rare. Pycnidia on leaves are subepidermal, usually hypophyllous, and are quite abundant. The spores at maturity issue in coils from the ostiole.

The fungus was studied extensively in artificial culture by Shear, wet sterilized cornmeal proving a most suitable medium. Pycnidia appeared in four to eight days after inoculation and spores were mature at twelve to eighteen days. Both pycnidia and perithecia were obtained in pure cultures. The rarity of cultures able to produce perithecia is explained by Shear on the assumption "that there is some inherent potentiality in the mycelium of the fungus in certain strains, races, or generations which causes it to produce the ascogenous stage whenever conditions for its growth are favorable, i. e., on favorable culture media without special reference to their exact composition or environment or on the leaves of its natural host." Conclusive infection experiments have not been made.

G. theæ Bern. [196] grows on tea leaves.

G. (Læstadia) buxi Desm. The perithecia develop on box leaves. It is probably saprophytic although sometimes considered a parasite.

Stigmatea Fries (p. 236)

Perithecia subepidermal, or subcuticular, thin, black; asci oblong, subsessile, 8-spored; spores ovoid-ellipsoid, 2-celled, yellowish or hyaline; paraphyses present. The ascigerous stage of two species of Entomosporium are said by Lindau [19] to belong to this genus. Atkinson, however, places them in the genus **Fabrea,** see p. 149.



F

FIG. 178.—Stigmatea. Asci and spores. After Winter.

S. juniperi (Desm.) Wint., on living leaves of Juniperus in Europe and America and on Sequoia in California.

Perithecia scattered, lenticular or subhemispheric, rough, 200–300 μ in diameter, asci rounded and obtuse above, abruptly tapering below into a short stipe, 60–70 x 20 μ; spores ovate-lanceolate, unequally 2-celled, yellowish-hyaline, 16–25 x 6–8 μ.

S. alni occurs on alder leaves in Europe.

Mycosphærella Johans. (p. 236)

Perithecia subepidermal, suberumpent, globose-lenticular, thin, membranous, ostiole depressed or short papillate; asci cylindric to clavate, 8-spored; spores hyaline or greenish, ellipsoid, 2-celled; paraphyses none.

This large genus of over five hundred species formerly known as Sphærella contains several serious plant pathogens. It is often found in its conidial forms as: Ramularia, Ascochyta, Septoria, Phleospora, Cercospora, Ovularia, Cylindrosporium, Phyllosticta, Graphiothecium, Phoma, Diplodia or Septoglœum. In many cases the relationship of the ascigerous and conidial forms is as yet but imperfectly known. The perithecia are usually found late in the season, often only on leaves that have borne the conidial stage in the summer and have then wintered.

M. fragariæ (Tul.) Lin.[197]

Perithecia on leaves, are produced late in the season, globose, subepidermal, membranous, black, thin-walled; asci few, clavate,

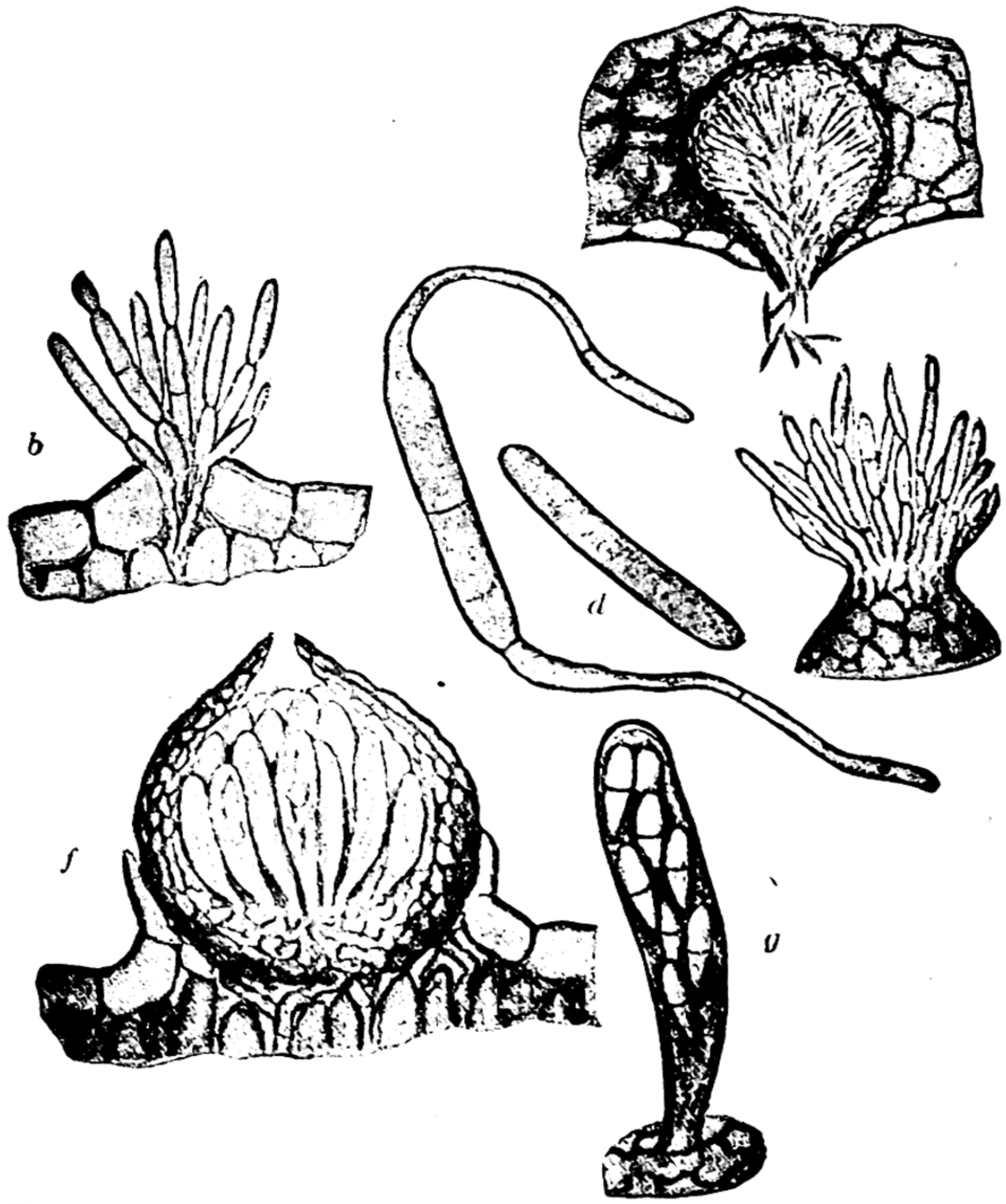


FIG. 179.—Mycosphærella fragariæ. *b*, conidiophores bursting through the epidermis; *c*, arising from apex of a pycnidium; *d*, summer spores, one germinating; *e*, section of a spermogonium; *f*, section of perithecium; *g*, ascus containing eight two-celled spores. After Longyear.

8-spored, 40 μ long; spores hyaline, 2-celled, with acute tips, 15 x 3–4 μ.

Conidia (=Ramularia tulasnei) abundant in early summer on reddish spots, stromatic, conidiophores simple; conidia elliptic 20–40 x 3–5 μ, 2 to 3-celled. On Fragaria.

The life history was first studied in 1863 by the Tulasne brothers under the name Stigmatea. The generic name was changed to Sphærella in 1882 and later to Mycosphærella.

The slender mycelium pervades the diseased areas disorganizing the host cells and resulting in reddish coloring of the sap. Observations of Dudley [198] indicate that the mycelium or portions of it can remain alive over winter in the host tissue ready to produce abundant conidia in the spring.

The most abundant conidial stage is the Ramularia-form (Fig. 179) which abounds all summer. Sowings of these conidia, under conditions of humid atmosphere, result in characteristic spots in from ten to eighteen days. Toward winter sclerotial bodies are formed from the mycelium. These in culture dishes have been seen to produce the typical summer conidia. Some of these sclerotia-like bodies have been reported as "spermogonia," bearing numerous "spermatia" 1 x 3 μ. Perithecia abound in autumn. These are larger than the spermogonia and are usually embedded in the leaf tissue, though they sometimes appear superficially. Conidiophores are often borne directly on the perithecium wall. Ascospores germinate within the ascus. From the mycelium resulting from ascospores Dudley [198] observed the formation of typical summer conidia.

M. grossulariæ (Fr.) [199]

Perithecia hypophyllous, gregarious, spherical, with minute ostiole, black; asci short-pedunculate, clavate, 55–66 x 8–12 μ; spores fusoid, filiform, curved or straight, uniseptate, hyaline, 26–35 x 3–4 μ.

It has been reported on the gooseberry associated with Cercospora angulata and Septoria ribis.

M. rubina (Pk.) Jacz.[200]

Perithecia minute, gregarious, submembranous, obscurely papillate, subglobose or depressed, erumpent, black; asci cylindric, subsessile, 70–80 x 10–12 μ; spores oblong, obtuse, uniseptate, generally constricted in the middle, 15 x 6–7 μ, upper cell broadest.

Conidia (=Phoma) are associated with the perithecia and are supposed to be genetically connected with them as is also a second spore form (=Coniothyrium).

The species is held responsible for bluish-black spots on raspberry canes.

M. cerasella Aderh.[201] is reported as the perithecial stage of Cercospora cerasella common on cherry.

M. sentina (Fr.) Schr.

Perithecia, 80–110 μ; on dead spots of leaves, the long ostiole erumpent; asci clavate, 60–75 x 11–13 μ, colorless; spores fusiform, curved or straight, 26–33 x 4 μ.

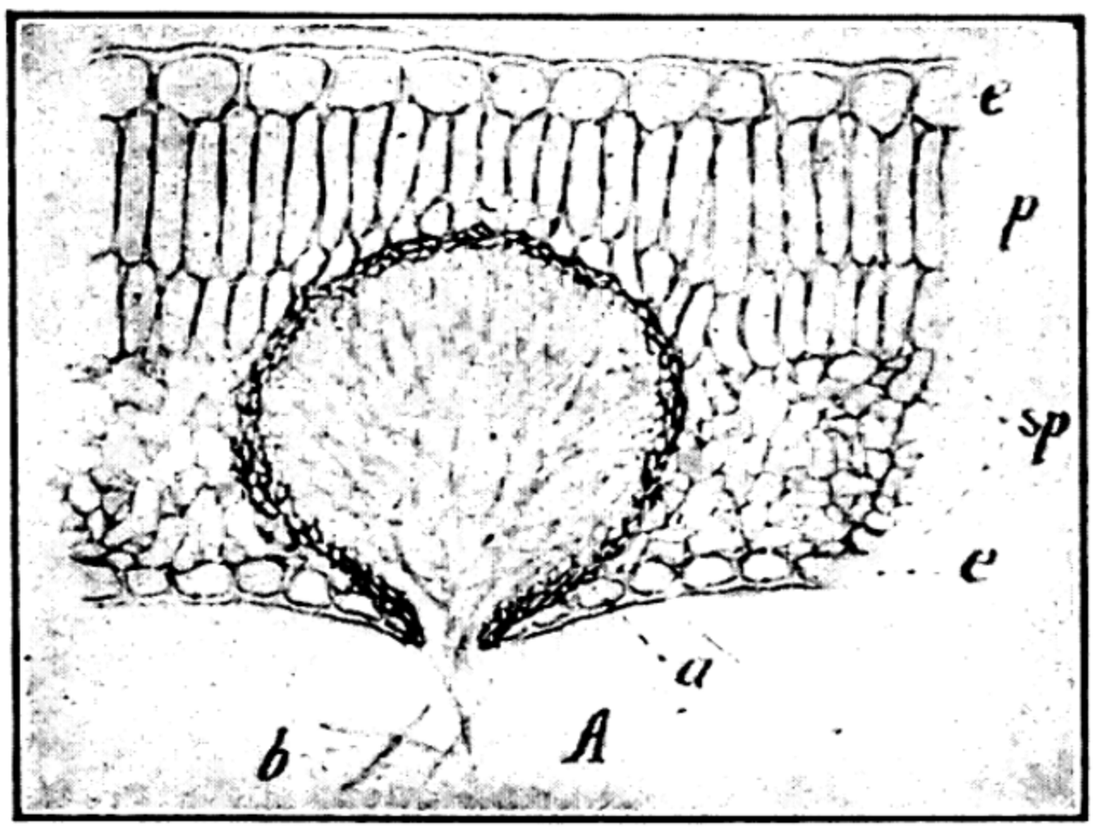


FIG. 180.—M. sentina, Septoria stage. Portion of a section through a pear leaf spot, showing *e*, *e*, epidermis; *p*, palisade cells *sp*, spongy parenchyma; *a*, S. piricola pycnidium, giving out spores, *b*. After Longyear.

Conidia (=Septoria piricola) borne in pycnidia which are similar in size and form to the perithecia; conidia filiform, curved, 3-celled, 40–60 x 3 μ. On pear and apple.

The conidial form was mentioned in America as early as 1897 by Atkinson [204] and was the subject of a comprehensive bulletin by Duggar in 1898.[203] The ascigerous stage was demonstrated by Klebahn in 1908.[202]

The pycnidia, mainly hypophyllous, are sunk deeply into the leaf tissue and are surrounded by a delicate pseudoparenchyma. The conidia are distinctly tinted, green or smoky.

The perithecia are numerous, and crowded on grayish spots, hypophyllous, on old wintered leaves. They are without stroma. Klebahn by inoculations (June, 1904) with ascospores secured spots in fifteen days and pycnidia in twenty-nine days, bearing the characteristic conidia. From ascospores he also made pure cultures which soon developed pycnidia with conidia. Pure cultures made from conidia in the hands of both Klebahn and Duggar have failed to give typical perithecia.



FIG. 181.—M. sentina. Conidial layer, conidiophores and conidia. After Klebahn.

M. citrullina (C. O. Sm.) Gros.

Perithecia roughish, dark-brown or black, depressed-globose to inverted top-shaped, usually with a papillate ostiole, densely scattered, erumpent, 100–165 μ; asci cylindric to clavate, 45–58 x 7–10 μ; spores hyaline, oblong-fusoid, constricted at the septum.

Conidia (=Diplodina citrullina) Pycnidia similar to the perithecia, spores 2-celled, hyaline, straight or curved, more or less cylindric, 10–18 x 3–5 μ.

The fungus was isolated in pure culture by Grossenbacher [205] from muskmelons by direct transfer of diseased tissue to potato agar. Inoculations from these cultures proved the fungus capable of entering healthy uninjured tissue, the disease showing about six days after inoculation. The brownish pycnidia originate from an extensive subepidermal, partially cortical, much-branched, brownish mycelium but soon break through and appear almost superficial. When moistened, spores issue in coils. Darker perithecia, nearly superficial, are found on old diseased spots. Both ascospores and conidia are capable of causing infection. Inoculations on pumpkin and watermelon gave positive results; these on cucumber, West Indian gherkin, squash, pumpkin, and gourd were negative. The same fungus has been reported as cause of canker of tomatoes.[206]

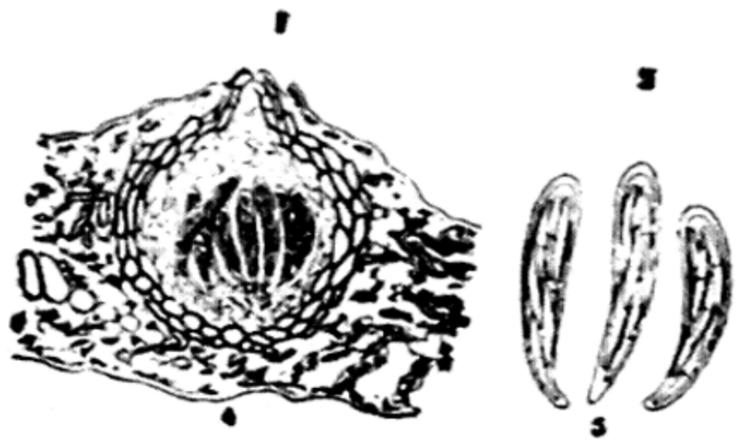


FIG. 182.—M. sentina. *A*, perithecium and asci. After Klebahn.

M. tabifica (P. & D.) Johns.[207–210]

Perithecia rounded, brown; asci oblong-clavate, 8-spored; spores hyaline, upper cell larger, 21 x 7.5 μ.

Pycnidia (=Phoma) subglobose; conidia elliptic, hyaline, 5–7 x 3.5 μ, escaping as a gelatinous cirrus.

This conidial form, common on beets causing leaf spot throughout the summer, is said by Prillieux and Delacroix to be connected with M. tabifica the perithecial form, which is found upon the dead petioles at the end of the season. Convincing evidence[209] of this connection seems wanting. The conidial stage[306] is variously known as Phoma betæ, Phoma sphærosperma, Phyllosticta tabifica. The Phoma-form from stems and rotten roots and the Phyllosticta-forms from leaves were both studied by Hedgcock [210] in pure cultures on many media and many inoculations were made, all leading to the conclusion that the Phoma and the Phyllosticta are identical.

M. tulasnei Jacz.[211]

Perithecia subglobose, minute; asci cylindric fusoid; spores

oblong, rather pointed, upper cell in the ascus somewhat larger than the others, 28 x 6.5 μ.

Conidia of two kinds, (1) (=Cladosporium herbarum) tufts dense, forming a velvety blackish-olive, effused patch, conidiophores erect, septate, rarely branched, often nodose or keeled; conidia often in chains of 2 or 3, subcylindric pale-olive, 1 to 3-septate, 10–15 x 4–7 μ. (2) (=Hormodendrum cladosporioidies Sacc.) Hyphæ erect, simple, bearing apically or laterally a tuft

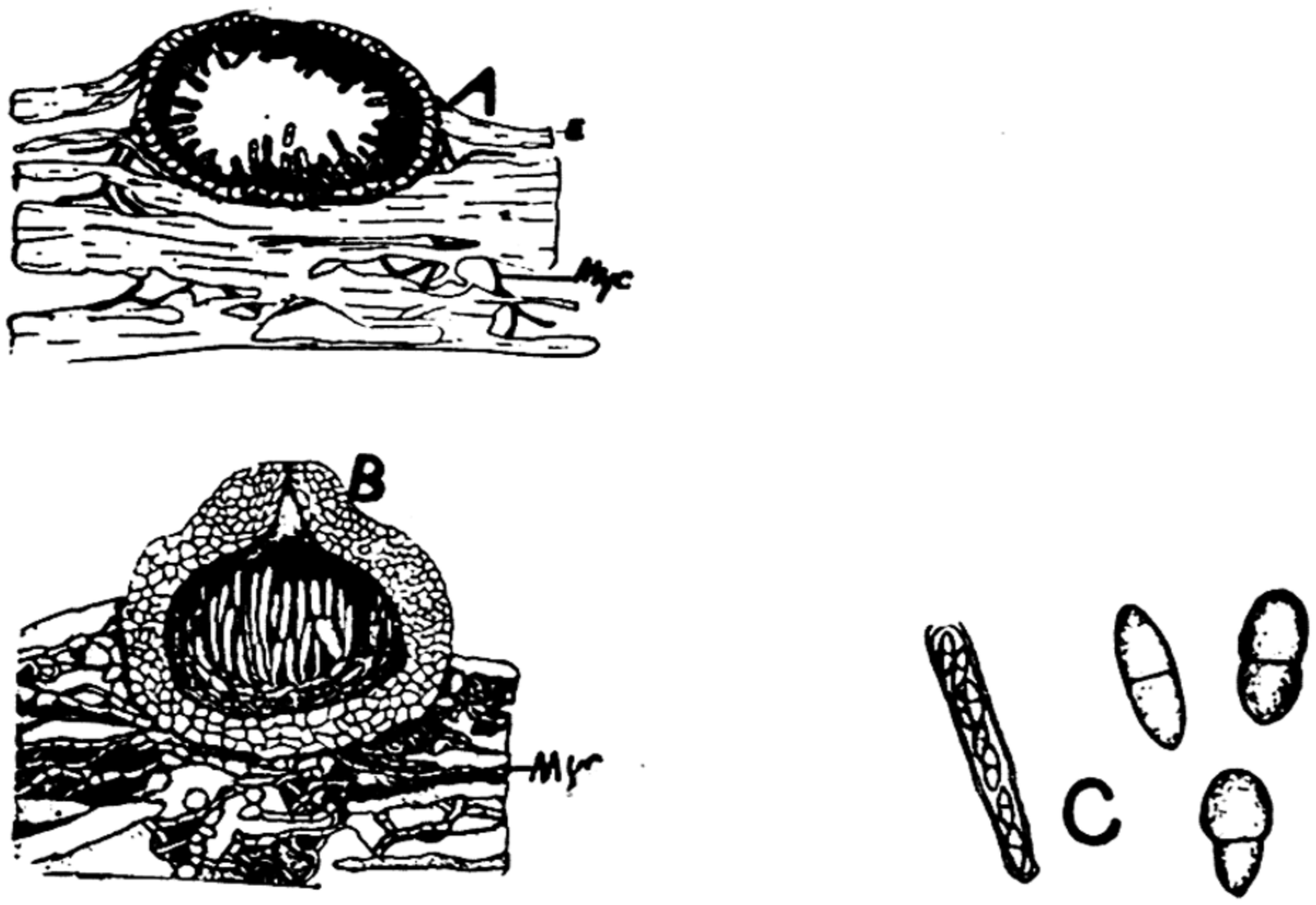


FIG. 183.—M. citrullina, A. pycnidium (Diplodia) in section, *B*, perithecium; *C*, ascus and spores. After Grossenbacher.

of small, elliptic, continuous, brown conidia in simple or branched chains.

It is the cause of serious disease in Europe, being especially injurious to cereals after a rainy season preceded by a drought and is found also parasitic on pea, apple, raspberry, cycad, agave and as a saprophyte almost anywhere.

M. stratiformans Cobb. affects sugar cane. The perithecial stage alone is known.[212] Further study is desirable.

M. gossypina (Cke.) Er.[213-217]

Perithecia ovate, blackish, partly immersed, 60–70 x 65–91 μ; asci subcylindric, 8–10 x 40–45 μ; spores elliptic to fusoid, constricted at the septum, 3–4 x 15–18 μ.

Conidia (=Cercospora gossypina); hyphæ flexuose, brown,

120–150 μ high; conidia attenuate above, 5 to 7-septate, hyaline, 70–100 x 3 μ. On cotton.

The intercellular mycelium is irregular, branched, septate, and produces tuberculate stromata from which the brownish hyphæ arise. The perithecia, much less common, are partly immersed in old leaves.

M. morifolia (Fcl.) Lin. in its conidial stages, Cylindrosporium mori and Septoglœum mori, affects Morus.

M. maculiformis (Pers.) Schr. grows on many trees. Especially common are its conidial stages Cylindrosporium castinicolum and Phyllosticta maculiformis.

M. rosigena E. & E. [218-219]

Amphigenous on reddish-brown, purple-bordered spots which are about 3–4 mm. in diameter; perithecia thickly scattered over the spots, minute, 60–75 μ, partly erumpent, black; asci subclavate to oblong, 25–30 x 8–10 μ; spores biseriate, clavate-oblong, hyaline, 1-septate, 10–12 x 2 μ, ends subacute.

It causes leaf spots of rose in America.

M. brassicæcola (=Phyllosticta brassicæcola) grows on cabbage.

M. punctiformis Pers. produces leaf spot on oak, lime, hazel;

M. fagi Auser. on beech;

M. pinifolia Duc. on pine leaves; [307]

M. abietis (Rost.) Lin. a leaf disease of balsam.[220]

M. taxi Cke. grows on yew;

M. hedericola Desm. on Hedera leaves;

M. gibelliana Pass. on Citrus leaves;

M. vitis Fcl. on grape leaves;

M. elasticæ Kr. [221] on Ficus elastica.

M. cydoniæ Vogl. [222] on quince is probably identical with M. sentina on pear and apple.

M. ulmi Kleb. occurs on elm with its conidial forms, a Phleospora and Phyllosticta bellunensis.

M. comedens Pass. is on the same host.

M. larcina Hart. and its conidial form Leptostroma larcinum affect larch, causing defoliation.

M. lœfgreni N. on oranges and **M. coffeæ** N. on coffee are tropical forms.

M. populi Schr. (=Septoria populi) is on Populus.[308]

M. pinodes Berk & Blox.

Perithecia numerous, 100–140 μ; asci oblong-cylindric, 58–62 x 12 μ; spores 2-rowed, 14–16 x 5.

Pycnidia (=Septoria pisi), with large ostiole; spores 35–45 x 3–3.5 μ, 1 to 3-septate. On pea stem and leaves.[309, 310]

M. primulæ is on primrose;

M. tamarindi on tamarinds in Africa.

M. cinxia Sacc. is on lilies, causing leaf blight;

M. fusca Pass. on the gladiolus;

M. coffeicola on coffee in Mexico.

M. shiraina Miy. and **M. hondai** Miy. are on rice.

M. convexula (Sch.) Rand.

Perithecia hypophyllous, gregarious or scattered, finally erumpent, 100–200 μ in diameter, papillate at maturity; no paraphyses; asci fasciculate, 54–100 x 9–11 μ, 8-spored; spores allantoid, 1-septate, hyaline, 13–27 x 3.5–5.5 μ.

Forming a leaf spot on pecans.[311]

An undetermined species of **Mycosphærella** has been reported on the grape by Rathay.[223]

Many other species are known on ferns, cereals, lilies, and various trees and herbs.

In the genus **Pharcidia. P. orzæ** Miy. is on rice.[305]

In **Sphærulina** the species **Sphærulina taxi** Mass. is injurious on yew leaves.

Pleosphærulina Passer (p. 236)

Perithecia subepidermal, erumpent, small, globoid or lenticular, black; asci 8-spored, clavate; spores muriform, hyaline; paraphyses none.

P. briosiana Pol. causes a leaf disease of alfalfa in Italy.

Pleosporaceæ (p. 223)

Perithecia sunken, at length erumpent, or from the first more or less free, membranous or coriaceous, usually papillate; asci clavate-cylindric, double-walled; spores variable, but usually colored, oblong, fusoid or elliptic; paraphyses present.

An order of some nineteen hundred species most of which are saprophytes, although several are parasites, some of considerable importance.

Key to Genera of Pleosporaceæ

Spores 1-celled
  Spores with blackish appendages, elongate, hyaline. ..... 1. **Urospora.**
  Spores unappendaged
    Spores elongate, hyaline or light yellow. ..... 2. **Physalospora,** p. 252.
    Spores elongate, fusoid, hyaline; tips bent. ..... 3. **Therrya.**
Spores 2-celled
  Spores with the 2 cells very unequal in size
    Upper cell the smaller; parasitic on Riccia. ..... 4. **Arcangelia.**
    Basal cell the smaller; saprophytes. ... 5. **Apiospora.**
  Spores with both cells about equal
    Perithecia hairy; spores hyaline or brown. ..... 6. **Venturia,** p. 253.
    Perithecia smooth
      Spores hyaline..... 7. **Didymella,** p. 255.
      Spores brown
        Perithecia not stromatic..... 8. **Didymosphæria,** p. 256.
        Perithecia borne on a stroma. .... 9. **Gibbellina,** p. 256.
Spores more than 2-celled
  Spores elongate, with cross walls only
    Spores appendaged
      Spores clavate, 4 to 6-celled, brown, the basal cell hyaline long-appendaged..... 10. **Rabentischia.**
      Spores filiform, many-celled, with filiform appendages..... 11. **Dilophia,** p. 257.
    Spores not appendaged
      Spores fusoid or elongate, blunt, never filiform or separating into cells
        Spores elongate, 3 to many-celled, hyaline or brown
          Spores with a thick, dark-brown epispore and a thin hyaline endospore, 4-celled, ellipsoid..... 12. **Chitonospora.**

Spores not as above, elongate
3 to many-celled hyaline or brown
Perithecia hairy. ..... 13. **Pocosphæria.**
Perithecia smooth
Spores hyaline..... 14. **Metasphæria,** p. 257.
Spores yellow or dark-brown..... 15. **Leptosphæria,** p. 257.
Spores fusoid, 7 to many-celled, the central cell enlarged and brown, the rest hyaline..... 16. **Heptameria.**
Spores fusoid, up to 30-celled hyaline or brown..... 17. **Saccardoella.**
Spores filiform, often separating into cells
Perithecia hairy. ..... 18. **Ophiochæta.**
Perithecia smooth. ..... 19. **Ophiobolus,** p. 259.
Spores muriform
Asci 8-spored
Spores appendaged..... 20. **Delacourea.**
Spores not appendaged
Perithecia hairy. ..... 21. **Pyrenophora,** p. 262.
Perithecia smooth. ..... 22. **Pleospora,** p. 259.
Asci 16-spored..... 23. **Capronia.**

Physalospora Niessl. (p. 251)

Perithecia subglobose, covered, membranous, or coriaceous, black, with the ostiole erumpent; asci clavate-cylindric; spores ovoid or oblong, continuous, hyaline or subhyaline; paraphyses present.

This genus contains over one hundred thirty species, a few of which are parasitic on twigs and leaves. Some species possess a Glœosporium as the conidial form.

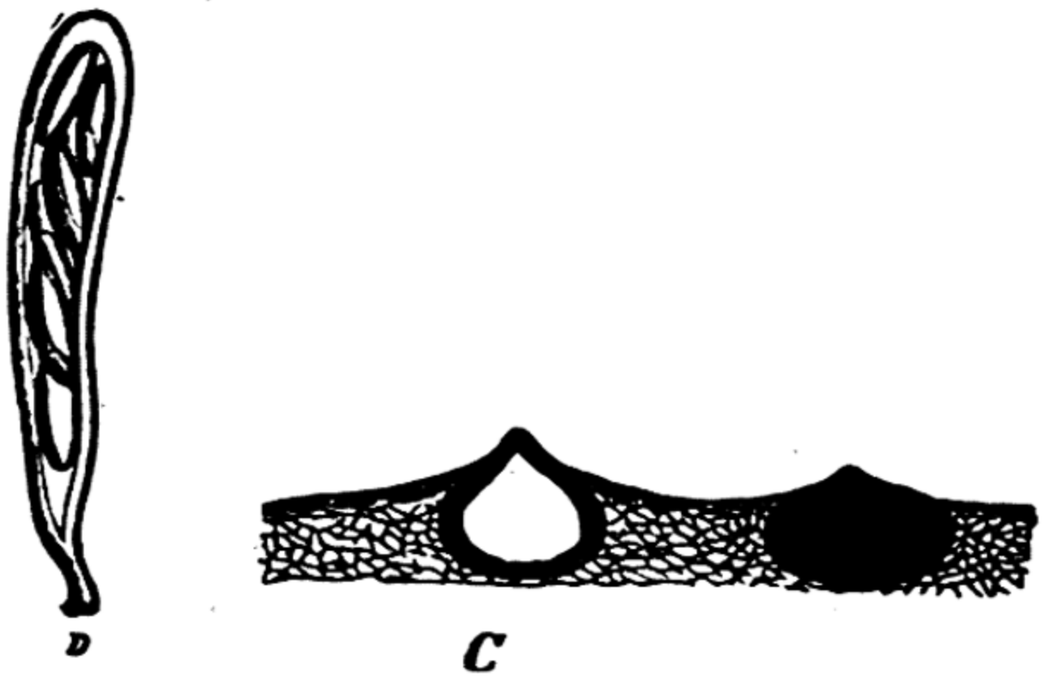


FIG. 184.—Physalospora. Perithecia and ascus. After Winter.

P. gregaria and its conidial stages Tetradia salicicola and

Macrodendrophoma salicicola cause black cankers on oziers in Ireland.[224]

P. abietina P. & D.[225] is found on Picea; **P. cattleyæ** Maub. & Las. in its conidial form, Glœosporium macropus[226] parasitizes Cattleya. **P. laburni** Bon. is on Cytisus.

P. woronini M. & F. is described as causing a disease of grapes in the Caucasus.[227]

P. vanillæ Zimm. is on vanilla;
P. fallaciosa Sacc. on banana leaves.

Venturia Cesati & de Notaris (p. 251)

Perithecia superficial or erumpent, bristly, ostiolate, membranous, dark colored; asci sessile or short stipitate, ovate or saccate; spores oblong to ovoid elliptic, hyaline or yellowish; paraphyses usually none.

The conidial stages in some cases belong to the form genus Fusicladium and constitute the parasitic portion of the life history of the fungus, the ascigerous form usually being limited to old or wintered parts of the host.

There are over fifty species, several of which cause diseases.

V. pirina Aderh.[230, 312, 313, 350]

Perithecia gregarious, smooth or bristly, globoid, 120–160 μ; asci cylindric; spores unequally 2-celled, yellowish-green, 14–20 x 5–8 μ.

Conidia (=Fusicladium pirinum) effused, velvety, blackish-olive, conidiophores short, wavy or knotted, thick-walled; conidia ovate fusoid, olive, becoming 1-septate with age, 28–30 x 7–9 μ.

It is found on the pear wintering in perithecial form on leaves, and in conidial form, or as mycelium on twigs.

V. inæqualis (Cke.) Aderh. (=V. pomi [Fries] Winter).

Perithecia globose, short-necked, 20–160 μ, smooth or bristly above; asci cylindric, 40–70 μ long; spores yellowish-green, unequally 2-celled, upper cell shorter and broader, 11–15 x 4–8 μ.

Conidia (=Fusicladium dendriticum) effused, velvety, forming dendritic patches of compact masses of erect closely septate brown mycelium; conidiophores closely septate, brown, 50–60 x 4–6 μ, wavy or nodulose; conidia solitary, terminal, obclavate,

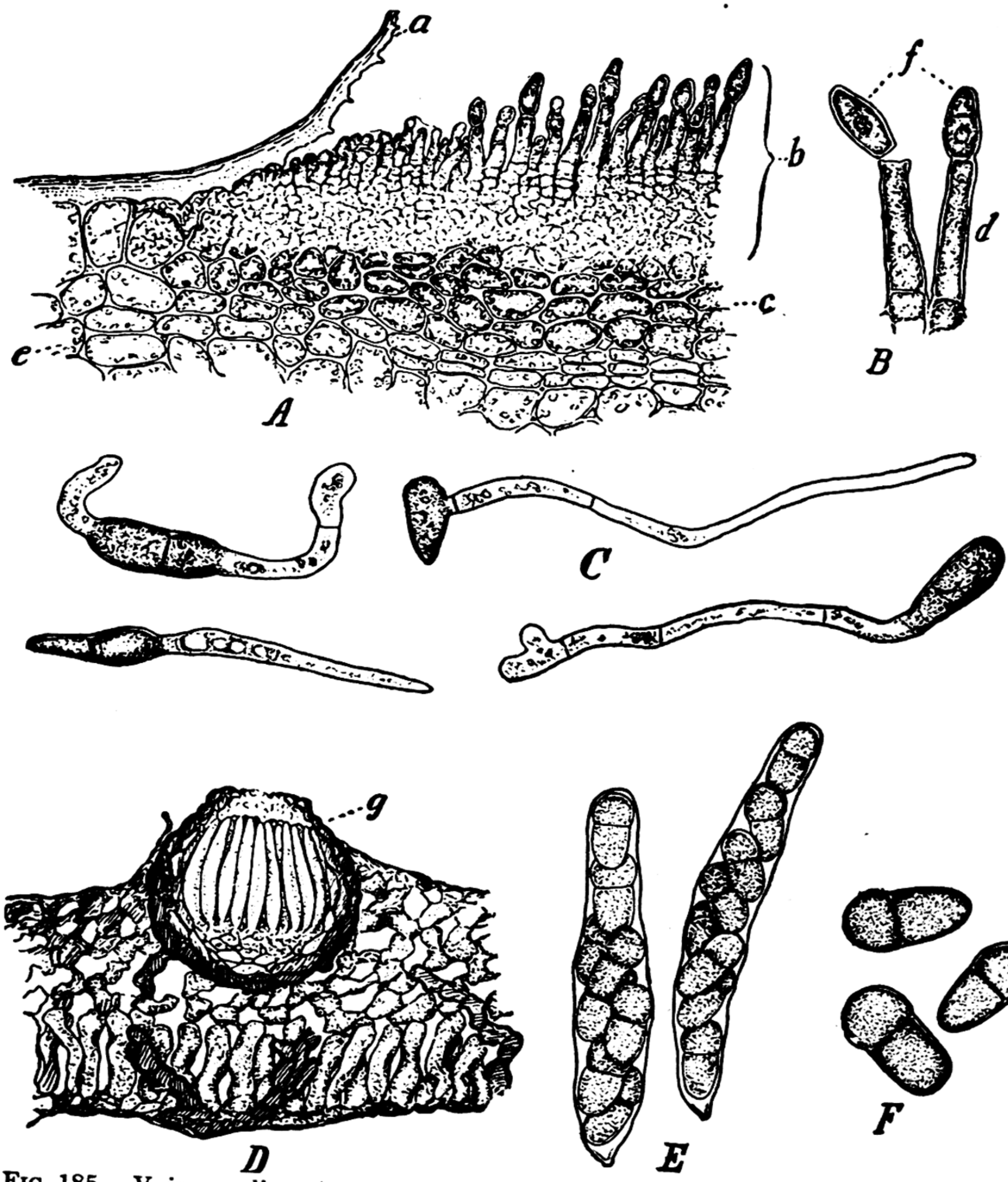


FIG. 185.—V. inæqualis. *A*, portion of a section through a scab spot on apple; *b*, spreading under and lifting the cuticle, *a*; *c*, partly disorganized cells of the apple; *e*, healthy cells of the apple. *B*, two conidiophores with summer spores *f*. *C*, spores germinating. *D*, portion of a section showing a perithecium and asci. *E*, two asci, each containing 8 two-celled spores, three of which are shown at *F*. After Longyear.

yellowish-olive, continuous when young but at length septate, 30 x 7–9 μ.

Its hosts are apple and other pomaceous fruits except the pear. Conidia of special form have been known under the name Napicladium soraueri.

The two last conidial forms have been long regarded as identical and are found in literature as Fusicladium dendriticum. The olive-green mycelium in both cases grows subepidermally in the leaf and fruit killing the epidermis and forming subepidermal stromata from which conidiophores are produced. Stromatal development is also said to be often subcuticular, resulting in a separation of the cuticle from the epidermis.

The conidia are produced apically on short stalks and as each conidium is cut off the conidiophore grows forward, leaving scars equal in number to the conidia produced. Pycnidia have been reported on the mycelium in twigs in winter.[352]

Perithecia first form on the lower leaf surface in October and mature in April. They are most abundant when protected by sod or piles of leaves, and appear as small black pustules often on grayish spots. Their connection with the conidial stage was first shown by Aderhold [231] and confirmed by Clinton.[232]

The fungus from apple was cultured on apple-leaf-agar by Clinton. Pure colonies developed in 4 to 5 days and infection was secured on leaves. Cultures from ascospores gave rise to typical conidia.

V. crategi Aderh. occurs on Cratægus.

V. cerasi Aderh. (=Fusicladium cerasi) is found on cherries. Aderholt [233] demonstrated the connection between the ascigerous and conidial forms.

V. ditricha (Fr.) Karst. (=Fusicladium betulæ) is found on birches; **V. tremulæ** Aderh. (=Fusicladium tremulæ) on aspen; **V. fraxini** Aderh. (=Fusicladium fraxini) on ash;

V. inæqualis var. **cinerascens** Lin. (=Fusicladium orbiculatum) on Sorbus.

Didymella Saccardo (p. 251)

Perithecia covered, membranous, globose-depressed, minutely papillate; black; asci cylindric or clavate· spores ellipsoid or ovate, 2-celled, hyaline; paraphyses none.

Of the some one hundred twenty species **D. citri** N. is of interest since it forms cankers on orange trees in Brazil.

Didymosphæria Fuckel (p. 251)

Perithecia immersed, later erumpent; asci cylindric to clavate, 8-spored; spores elliptical to ovate, 2-celled, brown.

This genus differs from Didymella chiefly in the dark-colored spores. It contains some one hundred twenty species and has occasional parasitic representatives on leaves and twigs.

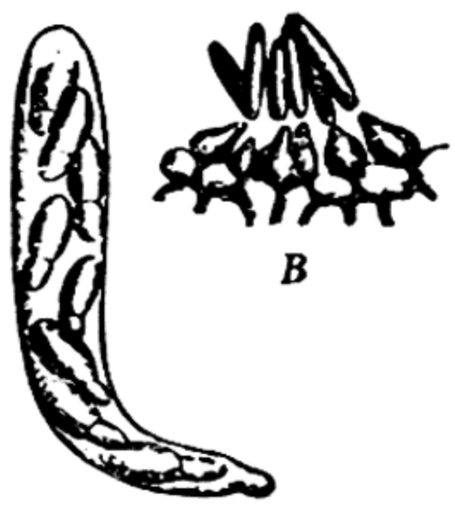


FIG. 186.—Didymella. *A*, ascus; *B*, hymenium of a pycnidium. After Brefeld.

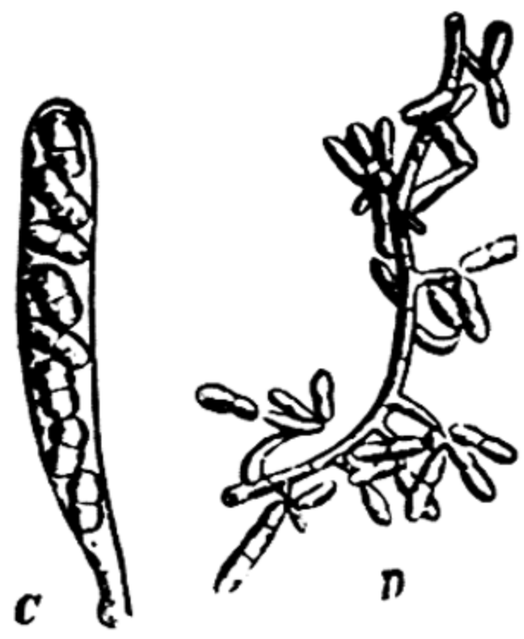


FIG. 187.—Didymosphæria. *C*, an ascus; *D*, conidiophore and conidia. After Brefeld.



FIG. 188.—Dilophia graminis. *J*, ascus; *K*, spore. After Winter.

D. sphæroides (Pers.) Fr. is on Populus leaves in Europe.

D. catalpæ.[344]

Perithecia very small, scattered, embedded in the tissue of the leaf, pyriform to nearly spherical, varying in width from 48–104 μ and in depth from 64–140 μ; ostiole broadly conical, erumpent; asci 8-spored, cylindrical, usually somewhat curved; paraphyses few or wanting; spores oblong-elliptical, hyaline or yellowish, uniseptate, constricted in the middle, 9.6–13 x 3–4 μ. On Catalpa.

D. populina Vuill., causes death of poplars in Europe.[234]

D. epidermidis Fr. is found on Berberis, Sambucus and Salix.

Gibbellina Passerina (p. 251)

Stromata black, sunken in the substratum, formed of thin, closely interwoven hyphæ; perithecia sunken in the stromata, globose;

asci elongate-globoid; spores elongate, 2-celled, brown; paraphyses present. Genus of one species.

G. cerealis Pers. causes a serious grain disease in Europe, especially of wheat in Italy.[235]

Dilophia Saccardo (p. 251)

Perithecia sunken, not erumpent, delicate, dark-colored, ostiole papillate; asci long-cylindric; spores elongate-fusiform to filiform, multicellular, each end appendaged, the appendages hyaline, the spores hyaline or yellow. Fig. 188.

There are three species, one of which **D. graminis** (Fcl.) Sacc. parasitizes rye and wheat in Europe. The conidial form Dilophospora graminis Desm. is especially common.

Metasphæria Saccardo (p. 252)

Perithecia clavate, sunken in a stroma, at first covered; leathery, dark, with ostiole; asci cylindric to clavate, 8-spored; spores ellipsoid, elongate, blunt or appendaged, 3 to many-celled; paraphyses filiform.

M. albescens Thûm. is on rice in Japan.

Leptosphæria Cesati & de Notaris (p. 252)

Perithecia at first subepidermal, at last more or less erumpent, subglobose, coriaceo-membranous, globose, ostiole usually papillate; asci subcylindric; spores ovoid, oblong or fusoid, two or more septate, olivaceous, yellowish or brown.

There are about five hundred species, many of which in the conidial forms embrace Cercospora, Phoma, Hendersonia, Sporidesmium, Septoria, Coniothyrium or Cladosporium.

L. coniothyrium (Fcl.) Sacc.[314, 315]

Perithecia gregarious, subepidermal, depressed, globose, black; ostiole papillate, erumpent; asci cylindric, stipitate, 8-spored, 66–96 x 4–6 μ; spores 1-rowed, oblong, 3-septate, constricted, fuscous, 10–15 x 3.5–4 μ.

Pycnidia (=Coniothyrium fuckelii), similar to perithecia; spores ovate, continuous, fuscous.

It occurs on black and red raspberries and numerous other hosts.

Stewart [314] verified the assumed identity of the conidial form with this ascigerous fungus by pure culture studies.

L tritici (Gar.) Pass [316] (=Pleospora tritici). On wheat.[236]

Perithecia innate, globose, black, papillate; asci clavate, short-stipitate, 8-spored; paraphyses filiform, 48–50 x 15–16 μ; spores 2-seriate, round, fusoid, 3-septate, constricted, pale, 18–19 x 4.2–5.5.

L. herpotrichoides d. Not.[236] parasitizes rye causing the stalks to break at the nodes;

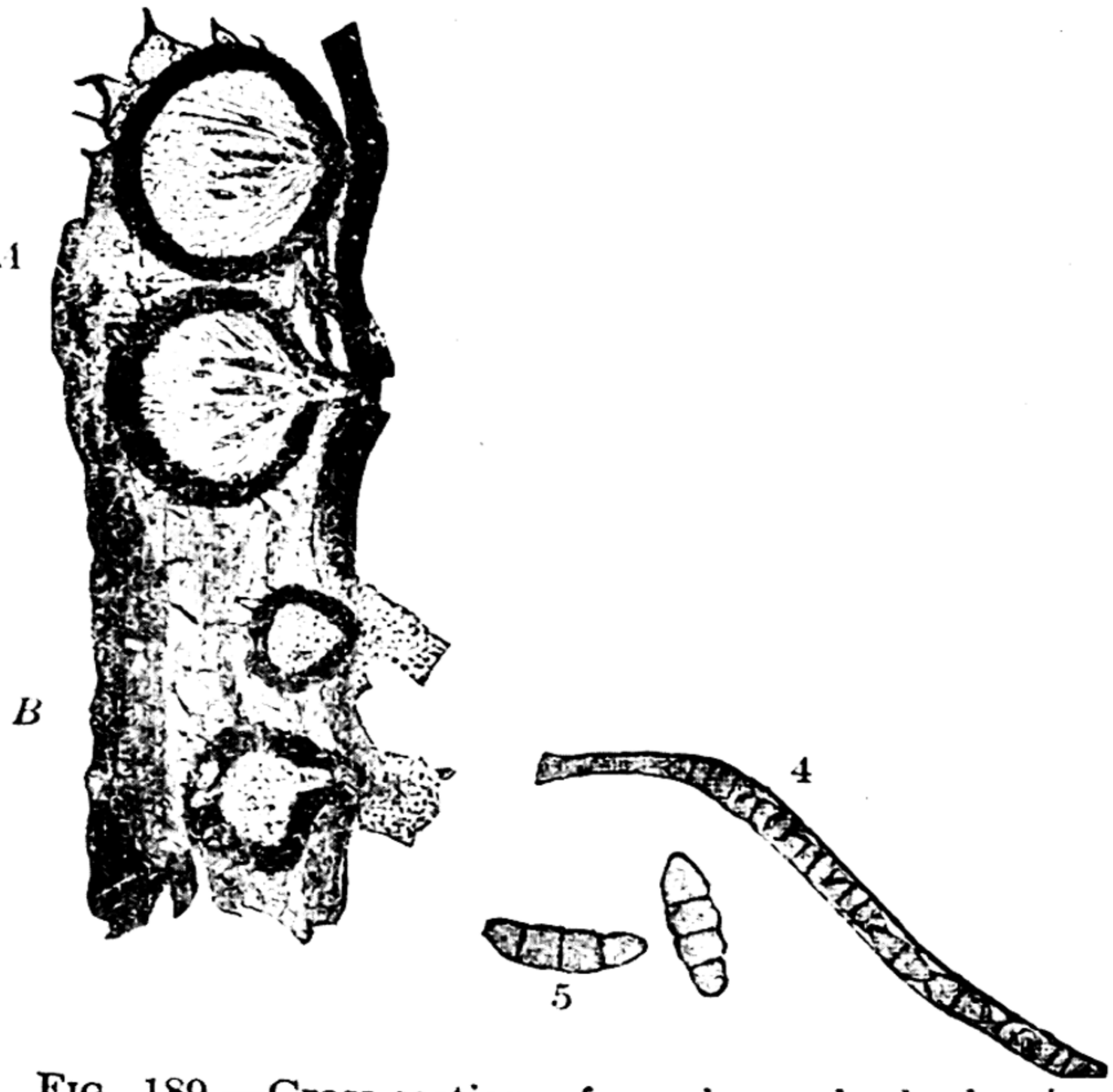


FIG. 189.—Cross-section of raspberry bark showing two perithecia of L. coniothyrium at the top, *A*, and two pycnidia of Coniothyrium fuckelii, at the bottom, *B*. 4. An ascus of L. coniothyrium. 5. Spores of L. coniothyrium. After Stewart.

L. sacchari V. B. d H. occurs on sugar-cane.[58]

L. napi (Fcl.) Sacc. (=Sporidesmium exitiosum) is found on rape; **L. phlogis** Bos. (=Septoria phlogis) on Phlox;

L. circinans (Fcl.) Sacc. kills alfalfa roots, potato, clover, beets and other hosts; [238]

L. vitigena Schul. occurs on grape tendrils;

L. stictoides Sacc. on Liriodendron; **L. rhododendri** on Rhododendron;

L. iwamotoi Miy. on rice;

L. taxicola R. K. on Taxus canadensis;
L. vagabunda Sacc. spots linden branches. Its conidial form is perhaps Phoma tiliæ.[239]

Ophiobolus Riess (p. 252)

Perithecia scattered, subglobose, submembranous, covered or suberumpent, ostiole papillate or elongate; asci cylindric; spores fusiform, hyaline or yellowish.



FIG. 190. — Ophiobolus. *B*, ascus; *C*, spore. After Lindau and Winter.

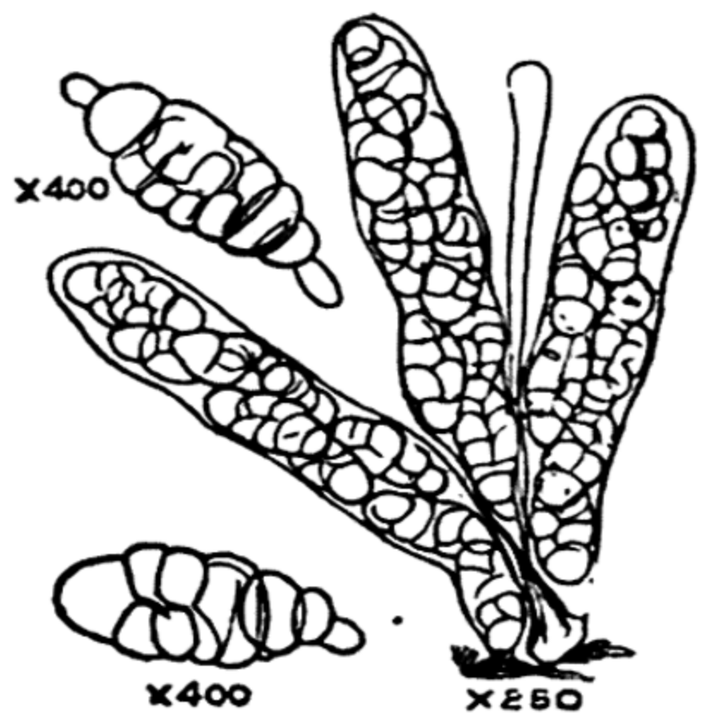


FIG. 191.— Pleospora from passion-fruit. The spores are just beginning to germinate, the end cells starting first. After Cobb.

A genus of some one hundred twenty-five species.
O. graminis Sacc. and **O. herpotrichus** Sacc. occur on grasses and are quite injurious in Europe.[317]
O. oryzeæ Miy. is found on rice.[305]

Pleospora Rabenhorst (p. 252)

Perithecia covered at first, later more or less erumpent, usually membranous, black, globose; asci oblong to clavate; spores elongate or ovate, muriform; paraphyses present.

Conidia occur as Macrosporium, Alternaria, Cladosporium, Sporidesmium, Phoma, Helminthosporium.

There are over two hundred twenty-five species, mostly saprophytic. Many conidial forms whose connection to this genus have not yet been definitely proved probably belong to it and are in many instances parasites.

P. tropeoli Hals. is reported as the cause of disease of the cultivated Nasturtium.[240]

Perithecia pyriform, 140–160 μ; asci oval, one-sided, spores hyaline or very light-olivaceous, 25–35 x 6–8 μ.

The Alternaria-form was grown from the ascospores by Halsted and from the Alternaria spores, grown in pure culture, perithecia were obtained in about twelve days.

P. albicans Fcl. occurs on chicory as Phoma albicans;

P. hyacinthi Sor. on hyacinths with its conidia as Cladosporium fasciculare; **P. hesperidearum** Cotton, in its conidial form, Sporidesmium pyriforme, causes a black mold on oranges.

P. herbarum (Pers.) Rab. (conidia=Macrosporium commune) is a common saprophyte which sometimes becomes parasitic.

P. pisi (Sow.) Fcl.[219] is found on the garden pea;

Perithecia and spores as in P. herbarum but spores more narrow.

P. ulmi. Fr. causes an elm leaf spot. **P. infectoria** Fcl. a common saprophyte, parasitizes tobacco.

P. oryzæ Miy. is on rice;

P. negundinis Oud. is injurious to nursery stock of Negundo;

P. putrefaciens (Fcl.) Fr. (conidia=Sporidesmium) is on carrots.

Pleosporæ on grains.[241, 318]

Several species of Pleospora with their attendant conidial forms of Helminthosporium and Alternaria are known on various grains and grasses. Cross inoculation experiments have shown here biologic specialization similar to that encountered among the Erysipheæ, in that conidia or ascospores from one host usually give negative results on host species other than that on which they grew. Thus Diedicke [242] says the Pleospora of Bromus cannot be grown on Triticum repens nor on cultivated barley or oats. Helminthosporium was formerly thought to be the conidial stage of all of these grain Pleosporas, but recent work of Diedicke shows that one form which he regards as P. trichostoma (Fr.) Wint.

possesses an Alternaria conidial form. Following Diedicke, the forms given below would be recognized.

P. bromi Died.

Perithecia brown, hairy; asci 189–288 x 34–59 μ, saccate, thin-walled; spores 2-seriate, golden-brown, 4-celled, 48–83 x 19–33 μ.

Conidia (=Helminthosporium bromi) on brownish spots, 108–150 x 13–20 μ, 5 to 7-celled, dark colored. On Bromus.

P. gramineum Died.

Conidia (=Helminthosporium gramineum); conidiophores short, subflexuose, light-brown; conidia solitary, elongate-cylindric, 4 to 7-celled, 15–19 μ wide and of variable length.

The mycelium invades the tissue causing long brown spots. These later become covered with an abundance of conidiophores which emerge through the stomata. Potter also reports invasion and complete occupation of ovaries by the mycelium.[22] Sclerotia-like bodies are formed on leaves and stems. They were first seen in artificial cultures of the fungus by Ravn [243] and have been since found in nature (Noack [244]).

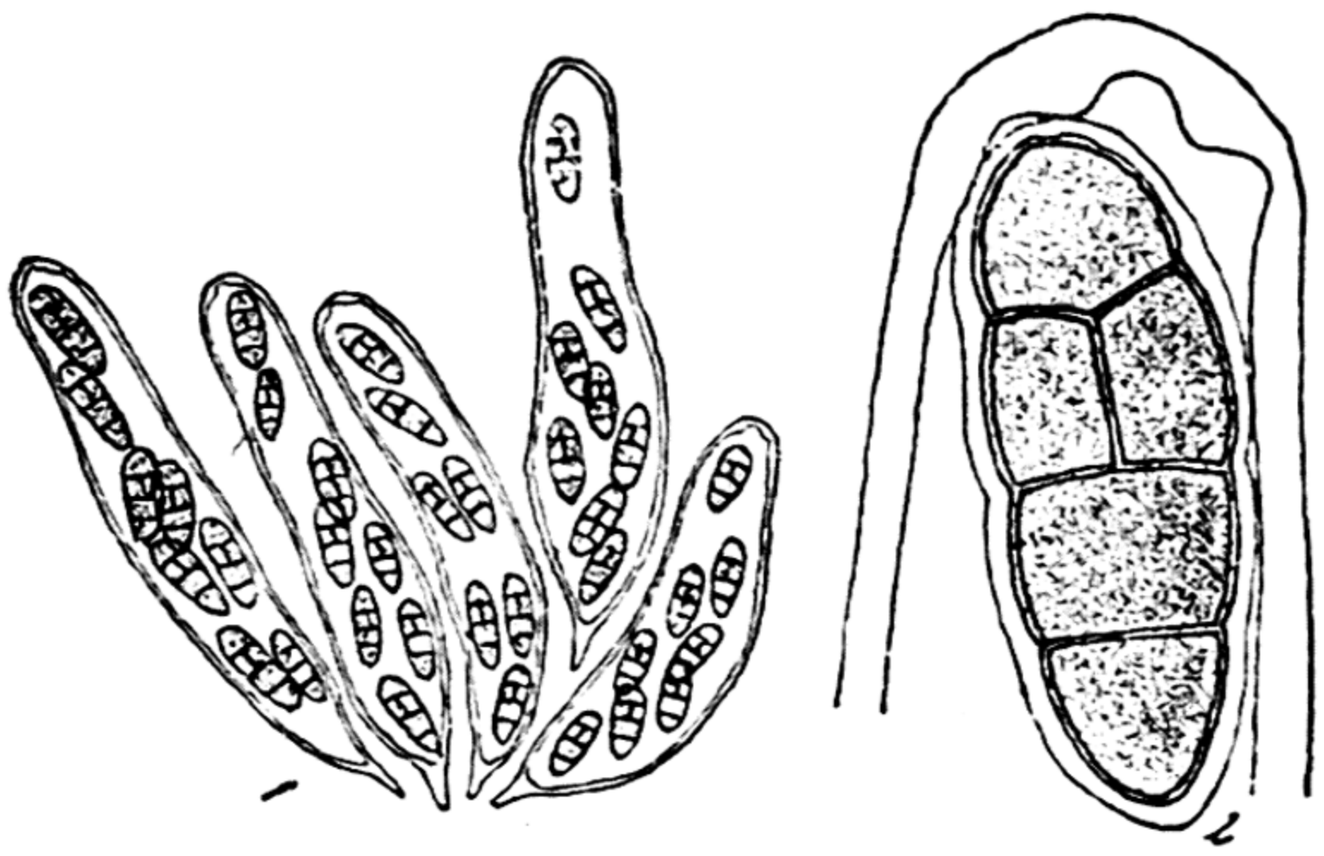


FIG. 192.—P. trichostoma. 1, group of asci, 2, a single spore at the apex of an ascus. After Diedicke.

The conidiospores have been shown to be long-lived, and spring infection begins largely from conidia carried over winter on seed. Extensive study was made of the conidial form by Ravn who found the mycelium to be of two kinds, one aërial and hyaline, the other strict and dark. It grew well on acid or neutral media.

Careful infection experiments (Ravn) proved the pathogenicity of H. graminum for barley but showed it incapable of infecting oats, rye or wheat.

Ravn regards the disease produced by H. gramineum as often general, not local, in that the mycelium may invade the growing points, resulting in infection of all the leaves.

P. tritici-repentis Died. is found on Triticum repens (=Agropyron repens.) Conidia=Helminthosporium tritici repentis.

P. trichostoma (Fr.) Wint. (=Pyrenophora trichostoma (Fr.) Sacc.[242]

Perithecia gregarious, innate, conical, black, ostiole surrounded by black hairs, which are simple, septate, 6–8 μ in circumference; asci clavate 300 x 40 μ; spores broadly oblong, obtuse, unequally 4 to 6-septate, muriform, brownish, 52 x 20 μ; paraphyses branched.

On rye with the conidial form =Alternaria trichostoma Died.

In the present state of our knowledge little is to be gained by recognition of these purely "biologic species," and all the forms may be grouped under the name P. trichostoma, recognizing the fact that it shows biologic differentiation.

Two hypothetical forms P. teres Died. and P. avenæ Died. pertain to Helminthosporiums of corresponding names.

Massariaceæ (p. 223)

Stroma none; perithecia separate, sunken, not erumpent, opening by a small pore, leathery or carbonous, compact; spores usually surrounded by a jelly-like substance; paraphyses present.

This family of ten genera and about one hundred twenty-five species contains only one parasite of interest.

Key to Genera of **Massariaceæ**

Spores 1-celled
- Spores not surrounded by a jelly-like substance. ..... 1. **Enchnoa.**
- Spores surrounded by a jelly-like substance. ..... 2. **Pseudomassaria.**

Spores several-celled
- Spores not muriform
  - Spores hyaline or yellow
    - Spores ellipsoid to spindle-shaped, several-celled, hyaline. ..... 3. **Massarina.**
    - Spores spindle-formed, curved, 3 to 4-celled, yellow..... 4. **Ophiomassaria.**
    - Spores 2 to 4-celled, elongate, hyaline. ..... 5. **Charrinia,** p. 263.

Spores brown
  Spores 2-celled
    Perithecia scattered irregularly. . . 6. **Phorcys.**
    Perithecia in circular clusters. . . . . 7. **Massariovalsa.**
  Spores more than 2-celled
    Spores ellipsoid to spindle-shaped, many-celled. . . . . 8. **Massaria,** p. 263.
    Spores cylindric, bent, 8-celled. . . 9. **Cladosphæria.**
Spores muriform. . . . . 10. **Pleomassaria.**

Massaria theicola Petch invades the ducts of the tea plant. The genus **Charrinia** is said by Viala & Ravaz [245] to contain the ascigerous form of Coniothyrium diplodiella (Speg.) Sacc.

Gnomoniaceæ (p. 223)

Perithecia sunken, with an elongate, cylindric, beak-like ostiole, rarely with a papillate one; leathery or membranous, rarely borne on a stroma; asci mostly thickened apically and opening by a pore; spores hyaline; paraphyses usually absent.

A family of about one hundred fifty species; four genera contain important pathogens.

Key to Genera of Gnomoniaceæ

Spores 1-celled
  Mouth of the perithecium short
    Asci cylindric, 8-spored. . . . . 1. **Phomatospora.**
    Asci clavate, 2-spored. . . . . 2. **Geminispora.**
  Mouth of the perithecium elongate, beak-like
    Mouth of the perithecium straight
      Asci many-spored. . . . . 3. **Ditopella,** p. 264.
      Asci 8-spored
        Spores ellipsoid or fusoid
          A clypeus present. . . . . 4. **Mamiania.**
          Stroma present. . . . . 5. **Glomerella,** p. 264.
          Stroma absent. . . . . 6. **Gnomoniella,** p. 273.
        Spores elongate fusoid, or filiform 7. **Cryptoderis.**
    Mouth of the perithecium recurved. . . 8. **Camptosphæria.**

Spores 2 or more-celled
  Asci 8-spored
    Spores elongate, 2 to 4-celled. ..... 9. **Gnomonia,** p. **274.**
    Spores fusiform, curved, 2-celled. ..... 10. **Hendersonia.**
  Asci many-spored; spores elongate, 2-celled
    Perithecia beaked..... 11. **Rehmiella.**
    Perithecia not beaked. ..... 12. **Rehmiellopsis,** p. **276.**

Ditopella de Notaris (p. 263)

Perithecia corticolous, covered, globose or somewhat depressed, ostiole suberumpent; asci subclavate, polysporous; spores oblong or fusoid, continuous, subhyaline; paraphyses none.

D. ditopa (Fr.) Schr. causes death of oak twigs in Europe; **D. fusarispora** d. Not., occurs on alder in Europe.

Glomerella Spaulding & von Schrenk [262, 342] (p. 263)

Perithecia cespitose, membranous, dark brown, rostrate, of a lighter color at the apex in early stages, flask-shaped, hairy, on or immersed in a stroma; asci sessile, clavate; spores 8, hyaline, oblong, 1-celled, slightly curved, elliptic; paraphyses usually none. Conidia=in part Colletotrichum and Glœosporium.

This genus was first described by Stoneman, from perithecia obtained from cultures of the conidia,[247] as Gnomoniopsis. On account of preoccupation it was renamed Glomerella by Spaulding and von Schrenk [248] in 1903. Studies by Shear have shown that there is much variation in pure line cultures both from ascospores and from conidiospores.[249] This leads to great uncertainty as to specific limitations as will become apparent in the paragraphs below. The conidial forms are very common and are usually parasitic. The ascigerous stages are comparatively rare. Sometimes they are found in nature; again only in artificial culture. Some forms known to be ascigerous may in one culture yield abundant perithecia while other cultures of the same fungus may persistently refuse to bear asci at all.

G. rufomaculans (Berk.) S. & S.[250-259]

Perithecia on decaying fruits, subspherical, more or less grouped;

asci subclavate, fugaceous, 55–70 μ; ascospores allantoid, 12–22 x 3–5 μ; conidial stage (=Glœosporium rufomaculans) with small sori, developing in more or less concentric circles, usually soon rupturing and pushing out spores in small pinkish masses; spores hyaline to greenish, chiefly oblong, unicellular 10–28 x 3.5–7 μ.

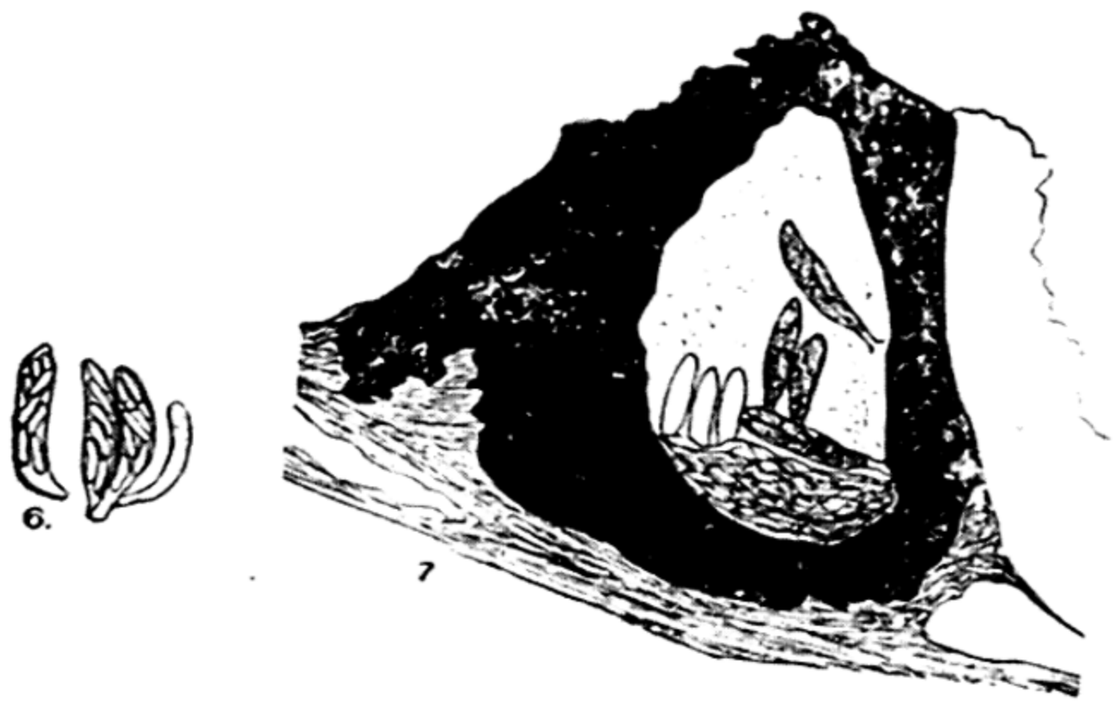


FIG. 193.—*7*, perithecium of G. rufomaculans showing asci *in situ*; *6*, asci showing detail. After Spaulding and von Schrenk.

The conidial stage of this fungus was first described by Rev. M. J. Berkeley in 1854 as a Septoria. It was later transferred to the form genus Glœosporium under which name the literature pertaining to it is largely to be found. See Southworth.[250] The ascigerous stage was found by Clinton [251] in 1902 and the fungus described as a Gnomoniopsis. In 1903, it was given the present name. A bibliography of some one hundred eighty titles is given by Spaulding and von Schrenk.[248]

The conidia germinating on apples send germ tubes through the skin, usually through wounds, occasionally through a sound surface.[251] The mycelium grows subepidermally, branching rapidly, intercellularly and intracellularly, absorbing the sugar and other nutrients present, and resulting in brown discoloration of cells and dissolution of their connection with neighboring cells. The mycelium is first hyaline but later, especially in the stromata, it may be quite dark. Acervuli soon appear, often in concentric rings, lifting the epidermis with their palisades of conidiophores. The latter, at first hyaline, later olivaceous, bear the numerous conidia, which are pinkish, rarely cream-colored, in mass. In germination the conidia become uniseptate and often on the tips of the young mycelium develop the dark thick-walled irregularly shaped spore-like structures, so common on the sporelings of the Melanconiales. These

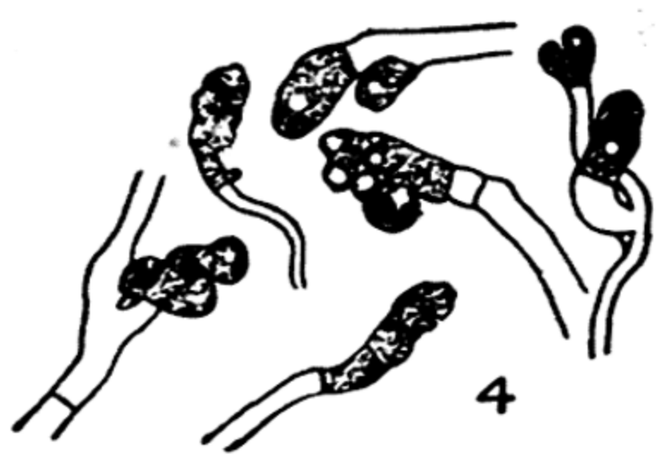


FIG. 194.—G. cactorum. Appressoria produced by germinating spores. After Spaulding and von Schrenk.

structures are regarded by Hasselbring [252] as organs of attachment to aid in infection, though they doubtless serve other purposes as well.

Perithecia of this species were first obtained by Clinton [251] who grew them in abundance on artificial media from sowings of conidiospores taken from pure cultures. The typical Glœosporium stage was also grown from ascospores.

Perithecia were also found in pure cultures on apple agar by Spaulding and von Schrenk. They appeared in black knotted masses of mycelium which were often 4–5 mm. in diameter, the perithecia varying from one to many in each such stroma. The asci were evanescent, disappearing soon after the spores matured.

That this fungus is the cause of a limb canker was suggested by Simpson's discovery of the canker in July, 1902 and was definitely proved by Spaulding and von Schrenck,[248] and by Burrill and Blair [253] in the same year.

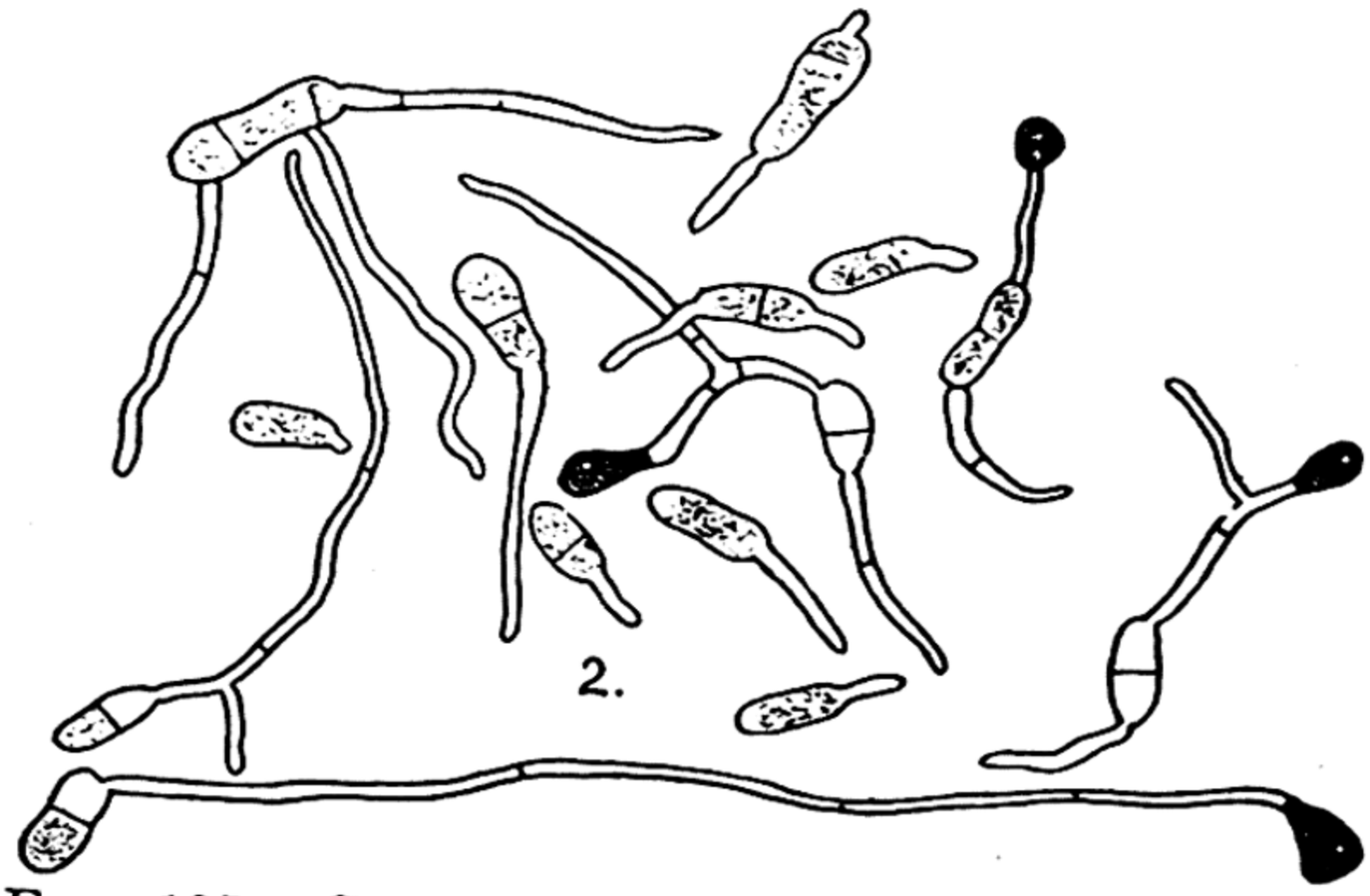


FIG. 195.—G. rufomaculans, germinating conidia. Note septa and appressoria. After Spaulding and von Schrenk.

In canker formation the mycelium grows in the live bark, killing it and the cambium. The cankers are thought to be comparatively short lived, perhaps surviving only the third year. Reciprocal inoculations between fruit and twigs have proved the fungus in the two cases to be identical. Conidia and ascospores develop on both fruit and twigs.

The fungus has been repeatedly grown in pure culture on numerous media by many investigators and many inoculations with conidia into both fruit and twigs have proved the causal relation of the fungus to the apple rot and twig canker. Inoculations from ascosporic material have given the same results.

That the spores may be insect-borne was shown by Clinton; [251] that they may also travel on the wind was shown by Burrill.[254]

The mycelium hibernates in limb cankers and in mummified fruit.[255]

It is impossible morphologically to distinguish the conidial stages of many species of Glœosporium and Colletotrichum growing on a great variety of hosts, and much inoculation work has been done to ascertain the relationships existing between these many forms. Thus the author [240] in Dr. Halsted's laboratory made inoculations as indicated in Fig. 367. Southworth cross inoculated a Glœosporium from grape to apple and from apple to grape; Stoneman from quince to apple.[247] Even such cultures give little evidence of difference between these forms and it usually is impossible to distinguish between the conidial forms on either morphological or biological grounds.



FIG. 196.—Plate culture of G. rufomaculans showing perithecia-bearing masses. After Spaulding and von Schrenk.

Some group under Glomeralla rufomaculans as its conidial forms, what were formerly known as Glœosporium fructigenum, G. rufomaculans, G. versicolor and G. læticolor.

Further studies of the ascigerous stages have led to consolidation rather than to segregation of species. Thus an ascigerous stage, a Glomerella, was obtained in pure culture from the following conidial forms by Shear and Wood:[258]

G. rufomaculans from grape, G. fructigenum from apple, G. sps. from cranberry, G. elasticæ from Ficus (see p. 544) a Glœosporium from Gleditschia, one from Ginkgo, Colletotrichum gossypii from cotton (see p. 271) and C. lindemuthianum. (See p. 547) from bean. These authors after careful study of these perithecia and cultures conclude that: "in the present state of

our knowledge, it may be best to regard the various forms we have studied as varieties of one species."

Among the hosts of G. rufomaculans may probably be numbered at least apple, grape, pear, quince, peach, tomato, egg-plant, pepper, sweet pea [256] and cherry.[257]

G. rufomaculans var. **cyclaminis** P. & C.[259]

Perithecia densely gregarious, indefinite, light-colored, around spots, brown, membranous, subglobose or distinctly rostrate, ostiolate; asci clavate-cylindric, apex pointed, 50–65 x 8–9 μ; spores oblong to elliptic, 16–18 x 4–4.5 μ.



FIG. 197.—G. rufomaculans. Pustules on apple, enlarged. After Spaulding and von Schrenk.

Conidia (=Colletotrichum); acervuli amphigenous, brownish, large; conidia oblong to linear, obovate, straight, or slightly curved, ends round, 12–15 x 4–5 μ; conidiophores long, slender; setæ free, short, rigid.

This variety is reported on greenhouse Cyclamens, causing leaf spotting. Mature perithecia were found on the leaves. Cultures from the ascospores gave a Colletotrichum as the conidial form and a similar Colletotrichum collected from the leaves in pure culture gave the Glomerella.

G. cingulata (Atk.) S. & S.

Perithecia cespitose, stromate, dark-brown, flask-shaped, membranous, 250–320 x 150 μ, shortly rostrate, more or less hairy; asci clavate, 64–16 μ; spores hyaline, elliptic, slightly curved, 20–28 x 5–7 μ.

Conidia (=Glœosporium cingulatum); acervuli 100–150 μ, rupturing the epidermis, in age black; conidiophores numerous,

crowded, simple, hyaline; conidia oblong to elliptic, straight or curved, basally pointed, 10–20 x 5–7 μ.

This was first described in conidial form as a Glœosporium by Atkinson [260] on privet as cause of cankers. The fungus was isolated and grown in pure culture. Later perithecia were obtained in the pure cultures.[247]

G. piperata (E. & E.) S. & S.

Perithecia cespitose, thinly membranous, dark-brown, pyriform, hairy; asci clavate; spores slightly curved, elliptic, 12–18 x 4–6 μ.

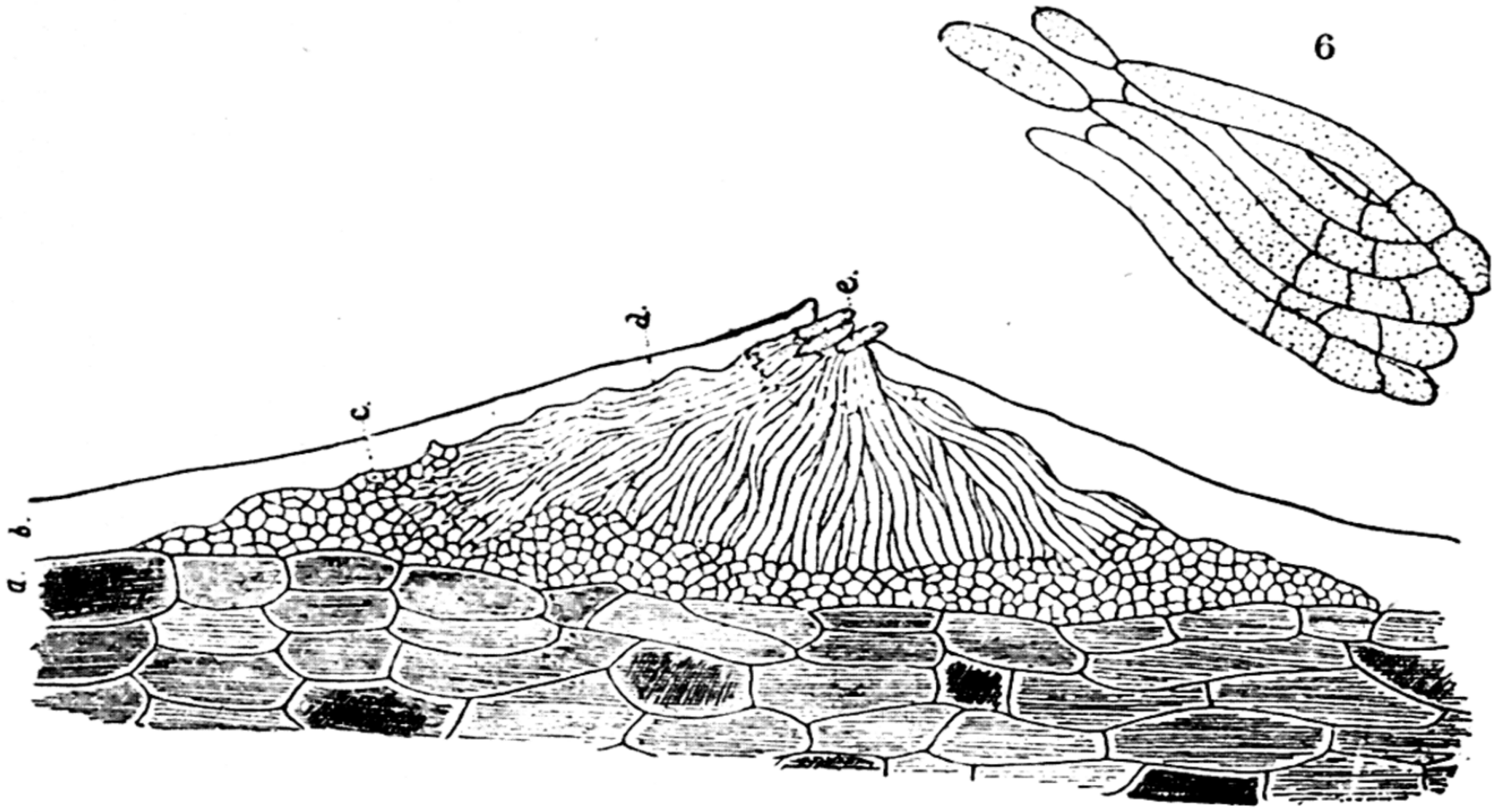


FIG. 198.—Diagrammatic section through acervulus of G. rufomaculans. *a*, parenchyma, *b*, cuticle, *c*, subhymenial fungous layer, *d*, conidiophores, *e*, spores, 6, conidiophores and conidia in detail. After Clinton.

Conidia (=Glœosporium piperatum) on circular or oval spots; acervuli pustular, concentrically arranged, conidia 12–23 x 5–6 μ.[261]

The ascigerous stage was grown from pure cultures of the conidia taken from pepper by Miss Stoneman [247] the perithecia appearing about a month after inoculation. Typical conidia were also secured from ascospore sowings.

G. cincta. (B. & C.) S. & S.[228]

Perithecia 180–280 μ, flask-shaped, membranous, cespitose; asci clavate, truncate or obtuse, 65–70 μ; spores elliptic, curved, 5–20 x 3 μ.[219]

Acervuli erumpent; conidia (=Colletotrichum cinctum) 12–15 x

3–4 μ, elliptic, guttulate; setæ present, but almost obscured by the spore mass.

The ascigerous stage was demonstrated by Stoneman [247] from pure culture studies. The conidial stage was described by Halsted [219] as the cause of a blighting of orchid leaves (Sobralia) in New Jersey.

Various hosts are orchids, Sarracenia, rubber plant, Dracæna [228] and Anthurium.[262]

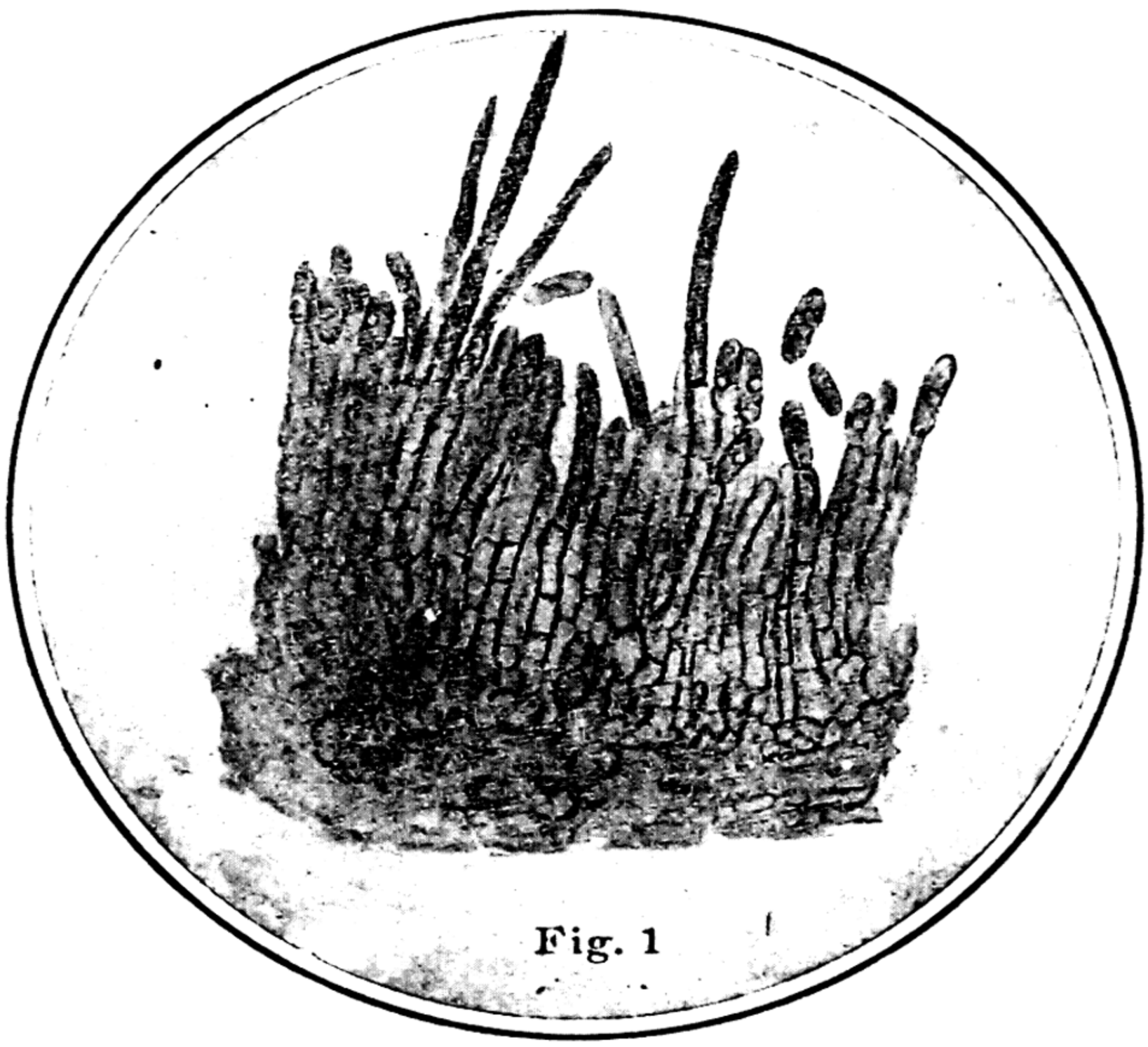


FIG. 199.—G. rufomaculans, acervulus showing conidia, conidiophores and setae. After Hasselbring.

G. rubicola (Ston.) S. & S.

Perithecia quite similar to those of G. piperata and G. cinta but lacking the apical tuft of hair and rather larger in size.

Conidia (=Colletotrichum rubicolum) forming large, dark-brown patches on the upper surface of the leaf; sori small, dark, suberumpent; conidia oblong, elliptic, 12.5 x 6 μ.

The conidial form on red raspberry was shown by Stoneman [247] by pure culture studies to possess this ascigerous stage.

G. psidii (Del.) Shel.[263–264]

Perithecia 200–300 μ, spherical, rarely distinctly beaked; asci

cylindric to broadly clavate, blunt, 45–55 x 9–10 μ; spores curved, continuous, granular, 13–15 x 5–6 μ.

Conidia (=Glœosporium psidii), acervuli subepidermal on definite spots, 90–120 μ; conidiophores hyaline, cylindric, 15–18 x 4–5 μ; conidia elliptic, oval, hyaline, 10–13 x 4–6 μ.

Artificial culture studies by Sheldon [263, 264] demonstrated the ascigerous stage. Extensive study was made of the growth on

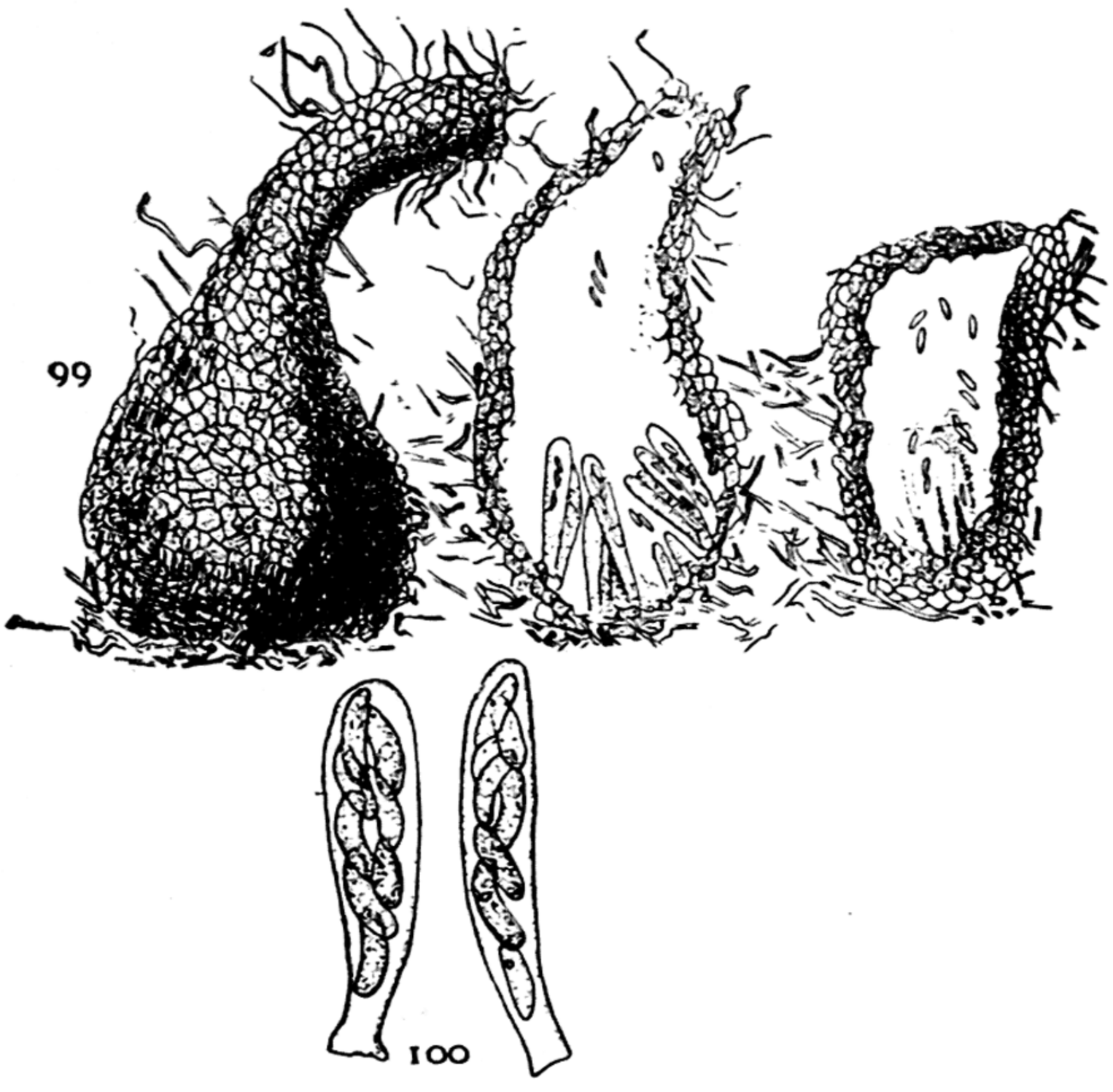


FIG. 200.—G. piperata, 99, perithecium external and in section. 100, asci in detail. After Stoneman.

apple-agar, apples, plums, etc. Two distinct forms of conidia were observed, one on loose hyphæ, the other in acervuli. The species should probably be regarded as a variety of G. rufomaculans.

It occurs on the guave.

G. gossypii (South.) Edg.

Perithecia distinct or crowded, very abundant, covered, dark brown to black, subglobose to pyriform, 80–120 x 100–160 μ, beak up to 60 μ long; asci numerous, clavate, 55–70 x 10–14 μ;

spores elliptic, hyaline, rarely curved, 12–20 x 5–8 μ; paraphyses long and slender, very abundant.

Conidia (=Colletotrichum gossypii), acervuli erumpent, conidiophores colorless, longer than the spores, 12–28 x 5 μ; conidia irregularly oblong, hyaline or flesh-colored in mass; setæ single or tufted, dark at base, colorless above, straight, rarely branched.

The conidial stage of this fungus was described by Southworth [265, 321] and independently by Atkinson [267, 319, 320] on cotton.

The ascigerous stage was first seen by Shear & Wood [258] in artificial culture and by them regarded as probably a variety of G. rufomaculans. Since these studies Edgerton [268] from examination of perithecia developed naturally in the open, has proposed it as a separate species.

The mycelium is richly branched and septate, usually hyaline but sometimes slightly smoky. It grows between and in the host cells which are often filled with it, causing collapse, loss of chlorophyll, and browning. Studies by Atkinson and by Barre [269] show that in case of diseased bolls the mycelium may extend through the pericarp, sporing on its inner wall; extend thence to the seeds; penetrate and grow in them, Fig. 201, and in the cells of the lint. Barre has shown that even the endosperm and cotyledons may be invaded, Fig. 201, and spores produced upon them while within the seed coats. Such seeds and lint may appear outwardly as though perfectly normal.



FIG. 201.—G. gossypii. Section of young boll, showing the fungus penetrating the hull and entering the young seed. Spores are being produced upon the outer portion of the hull and upon the surface of the young seed coat. After Barre.

The conidia are formed in acervuli, subtended by stromata. Setæ, from few to many increasing with age of the acervulus, are present and conidia are occasionally found on them. In germination conidia usually develop one, sometimes two septa and produce dark chlamydospores. Acervuli are common on bolls, less so and smaller on leaves and stems.

The perithecia as found in the field by Edgerton in Louisiana

were usually entirely embedded, with the beaks only protruding and were often numerous and crowded. Cultural evidence that Edgerton's specimens were actually genetically connected with the cotton anthracnose are wanting.

The fungus has been repeatedly studied in pure culture and numerous inoculations have thoroughly proved its pathogenicity, the disease usually showing within a few days after inoculation, though sometimes incubation is delayed much longer.

Infection of stems is often at a wound such as a leaf scar; or on leaves at some point of weakness. Cotyledons and young plants are especially susceptible. On bolls infection is common at the line of dehiscence of the carpels. According to Barre, there is evidence that the fungus may destroy the contents of the boll before it shows upon the outside. Barre showed that 44% of flowers that received spores within ten hours after opening produced diseased bolls; but inoculations by spraying produced no results on bolls after they were three-fourths grown.

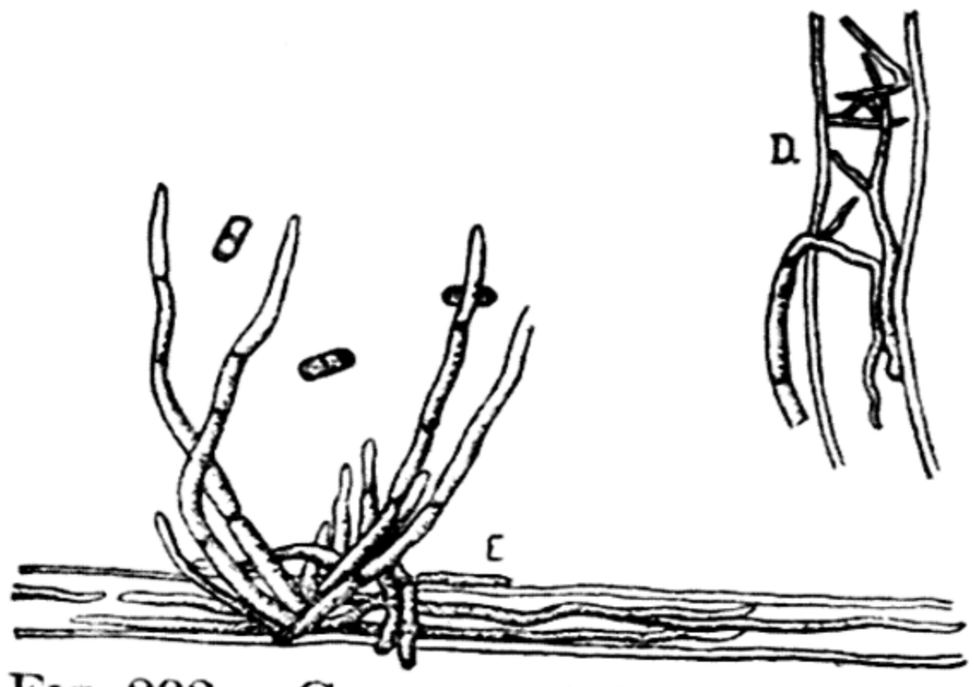


FIG. 202.—G. gossypii, D, and E, fungus growing in cotton lint fibers. After Barre.

Seed from a field that bore 35% infected bolls gave on germination, 12% of infected seedlings, the disease appearing upon cotyledons or hypocotyls even before they unfolded. Atkinson [270] found that conidia five months old were alive, but that at seven months they failed to germinate. Barre also found the conidia and the mycelium of the fungus to be comparatively short lived.

G. atrocarpi Del. on Atrocarpus leaves has been described as a perfect stage of Glœosporium atrocarpi Del.

A fungus on Cattleya [271, 272] described by Maublanc & Lasnier as a Physalospora should perhaps be considered as a Glomerella.

Gnomoniella Saccardo (p. 263)

Perithecia sunken and usually remaining so, with a long cylindric, erumpent ostiole, leathery, black; asci ellipsoid or fusoid,



FIG. 203.—G. tubiformis, perithecia. After Winter.

apically thickened and opening by a pore; spore elliptic, 1-celled, hyaline; paraphyses none.

This genus of some twenty-five species contains **G. tubiformis** (Tode) Sacc. which is said to be the ascigerous stage of Leptothyrium alneum Sacc. growing on Alder. **G. fimbriata** and **G. coryli** are found on hornbeam and hazel respectively.

Gnomonia Cesati & de Notaris (p. 264)

Perithecia covered, or erumpent, submembranous, glabrous, ostiole more or less elongate; asci ellipsoid or fusoid, apically thickened, opening by a pore; spores elongate, hyaline, 2 to 4-celled; paraphyses none.

There are some sixty species. Fusicoccum, Myxosporium, Sporonema, Glœosporium, Marssonia, Asteroma, Leptothyrium occur in some species as the conidial form. The ascigerous form usually follows as a saprophyte after the parasitic conidial stage.

G. veneta (Sacc. & Speg.) Kleb.[273, 322, 323, 335]

Perithecia immersed, subglobose or slightly flattened, 150–200 μ, short, rostrate; asci long-clavate, 48–60 x 12–15 μ, generally bent at right angles at the base, apically very thick, opening by a pore; spores 14–19 x 4–5, straight or slightly curved, unequally 2-celled, the upper cell longer.

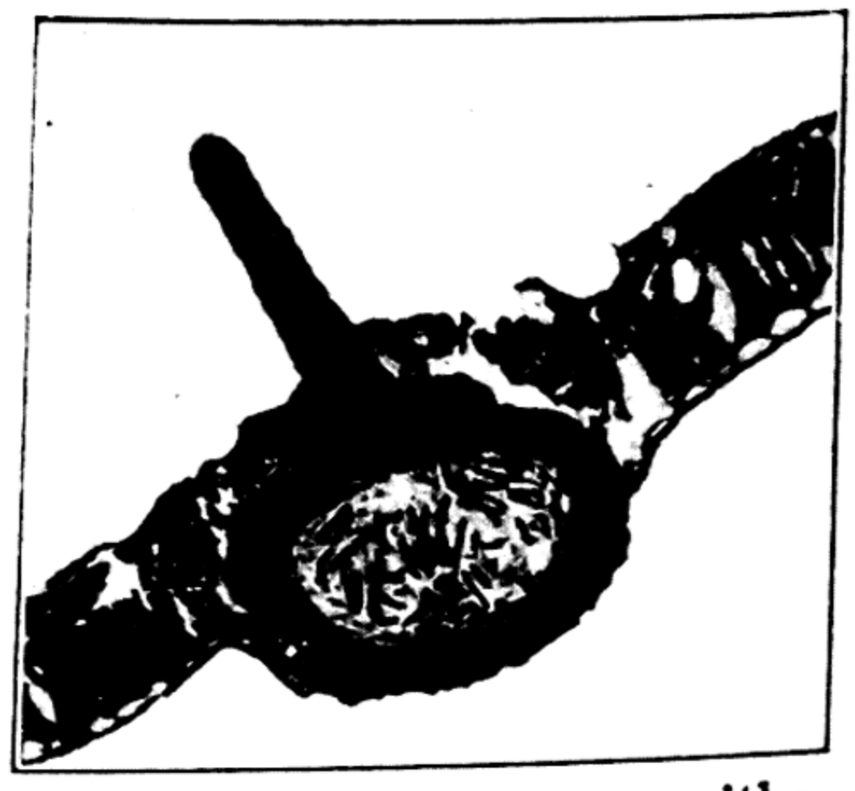


FIG. 204.—G. veneta, perithecium. After Edgerton.

Conidia variable in habitat, and habit. (1) (=Glœosporium nervisequum) acervuli subcuticular 100–300 μ; conidiophores short, conidia oozing out in a creamy-white mass, hyaline, ellipsoid, 10–14 x 4–6 μ, pointed at one end and rounded at the other. (2) (=G. platani) acervuli subepidermal, conidiophores long; conidia as above. (3) (=Discula platani=Myxosporium valsoideum) forming minute, subepidermal, erumpent pustules on twigs; conidia elliptic to oblong, hyaline, 8–14 x 4–6 μ; (4) (=Sporonema platani

=Fuscicoccum veronense). Pycnidia formed on old leaves on the ground, erumpent, subcuticular, brown, 200–300 μ; conidia numerous, oblong, ovoid to fusoid, 7–11 x 3–4 μ.

The conidial form on sycamore and oak, first described in 1848, is common on leaves and young branches, the mycelium checking the sap-flow and causing death of surrounding tissue. A stroma is formed on the outer layers of the mesophyll and from this arise the short conidiophores to constitute the acervulus.

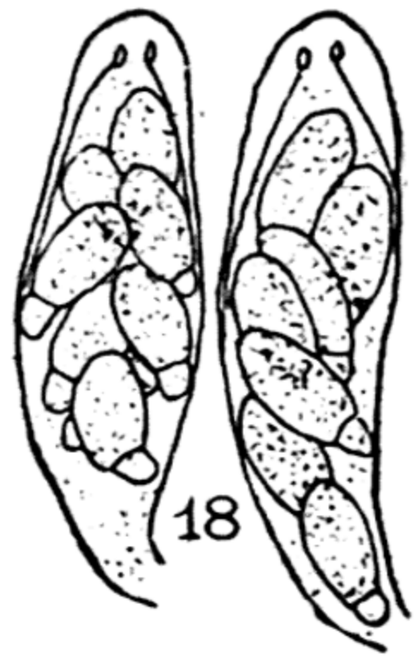


FIG. 205.—G. veneta, asci and spores. After Edgerton.

Infection experiments by Tavel [273] gave negative results. Other infection experiments have also been unsatisfactory.

The ascigerous form was first found by Klebahn [274] on old leaves on which it matured about Christmas time. While the conidia are uniform in shape four modes of development are found, as stated above.

Pure cultures from all the spore forms were compared by Edgerton [322] confirming Klebahn's conclusion as to their identity. Cultures by Stoneman [247] showed the forms on sycamore and oak to be the same.

G. leptostyla (Fr.) Ces. & d. Not.

Perithecia conic, short-beaked; asci subclavate, 45–65 x 10–12 μ; spores fusoid, curved, 18–22 x 4 μ, hyaline. Conidial phase (=Marssonia juglandis). Acervuli gregarious, hypophyllous, rounded; conidia obovoid, 8–10 x 4–5 μ, 1-septate, pointed above, truncate below, greenish.

The connection between the conidial and ascigerous forms was demonstrated by Klebahn [275] by pure cultures and by ascosporic infection. The conidial form is common on walnut leaves; especially severe on the butter-nut (Juglans cinerea) often defoliating this host in mid-summer.

G. quercus-ilicis Berl. occurs on oak leaves in Italy.

G. erythrostoma Auer. is the cause of a disease of cherry leaves in Europe; [276, 351]

G. padicola Kleb. is the ascigerous stage of Asteroma padi which is widely distributed in Europe on Prunus.

G. oryzæ Miy. occurs on rice.[277]

G. rubi Rehm may occasionally cause disease of blackberry canes.[278]

Rehmiellopsis Bubak & Kabat (p. 264)

Similar to Rehmiella except that the perithecia are not beaked and the pycnidia do not have a definite opening.

R. bohemica Bub. & Kab.; (conidia=Phoma bohemica)[246] occurs as a parasite on fir needles.

Clypeosphæriaceæ (p. 223)

Perithecia immersed, astromatic or with a pseudostroma built of hyphæ which, with the adjacent substratum, forms a thin clypeus that is usually evident only above; ostiole short to long-beaked, erumpent, walls mostly carbonous to membranous; paraphyses usually present.

A small family chiefly saprophytes.

Key to Genera of Clypeosphæriaceæ

Spores 1-celled	
Perithecia soft-membranous, spores hyaline or brown	1. **Trabutia.**
Perithecia leathery; spores brown	2. **Anthostomella,** p. 276.
Spores more than one-celled	
Spores with cross walls only	
Spores cylindric, ellipsoid or fusiform	
Spores hyaline, 1 to 3-septate	3. **Hypospila.**
Spores brown	
Spores elongate	4. **Clypeosphæria.**
Spores fusiform, more than 4-septate, sometimes muriform	5. **Phæopeltosphæria.**
Spores filiform, hyaline to yellow	6. **Linospora.**
Spores muriform	
Spores ovate, brown	7. **Peltosphæria.**
Spores short, fusiform, hyaline	8. **Isothea.**

Anthostomella Saccardo

Mycelium fusing with the upper surface of the substratum to form a thin, black, rounded pseudostroma; perithecia sunken, sub-

globose, with a short, conical ostiole, walls black, carbonous to leathery; asci cylindric, 8-spored; spores elliptic, continuous, brown, unappendaged; paraphyses usually present.

Over one hundred species, chiefly saprophytes.

A. sullæ Montem. occurs as the cause of a leaf spot on sulla.[281]

A. bohiensis (Hmp.) Speg. is on cacao;
A. destruens Sh. on cranberry;
A. coffeæ Desm. on coffee.[237, 282]

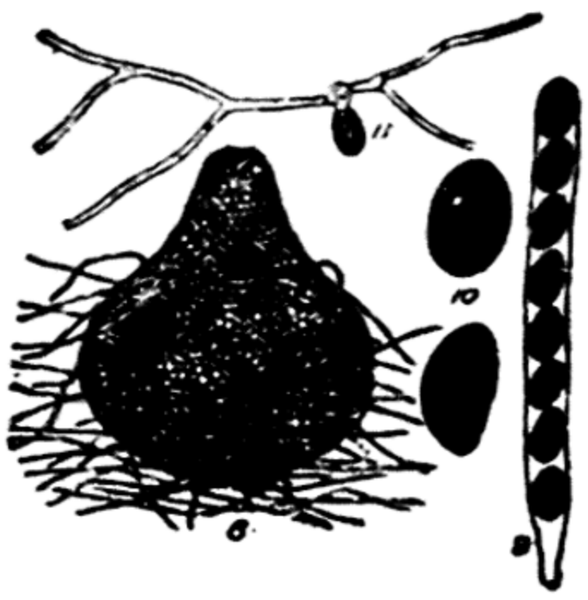


FIG. 206.—A. destruens. *8*, perithecium; *9*, ascus; *10*, spores; *11*, germinating spore. After Shear.

Valsaceæ (p. 223)

Stroma effused, subglobose, conic, or pulvinate, often indefinite; perithecia sunken in the stroma, scattered or clustered, black, leathery; asci cylindric or clavate; paraphyses usually present.

Over one thousand species, chiefly saprophytic. Conidia are present on hyphæ or in pycnidia.

KEY TO GENERA OF Valsaceæ

Spores 1-celled
- Spores cylindric or ellipsoid, with a brown membrane. ..... 1. **Anthostoma.**
- Spores ellipsoid, curved or not, with a hyaline membrane. ..... 2. **Valsa,** p. 278.

Spores more than 1-celled
- Spores with cross walls only
  - Spores hyaline
    - Spores unappendaged
      - Spores ellipsoid or fusoid 2 to 4-celled. ..... 3. **Diaporthe,** p. 278.
      - Spores elongate, fusoid, constricted in the middle. ..... 4. **Vialaea.**
    - Spores appendaged, 1 appendage at each end and 2 or 3 in the middle. ..... 5. **Caudospora.**
  - Spores brown
    - Spores 2-celled, ellipsoid ..... 6. **Rhynchostoma.**
    - Spores many-celled, fusoid ..... 7. **Kalmusia.**

Spores muriform
  Stroma effused
    Spores hyaline ..... 8. **Thyridella.**
    Spores colored. ..... 9. **Thyridium.**
  Stroma none or pulvinate. ..... 10. **Fenestella.**

Valsa Fries (p. 277)

Perithecia on a more or less definite stroma, immersed, the ostiole erumpent, black, firm; asci globose to cylindric, often long-pedunculate; spores 1-celled, rarely 2-celled, cylindric, rounded, hyaline or light-brown; paraphyses none.

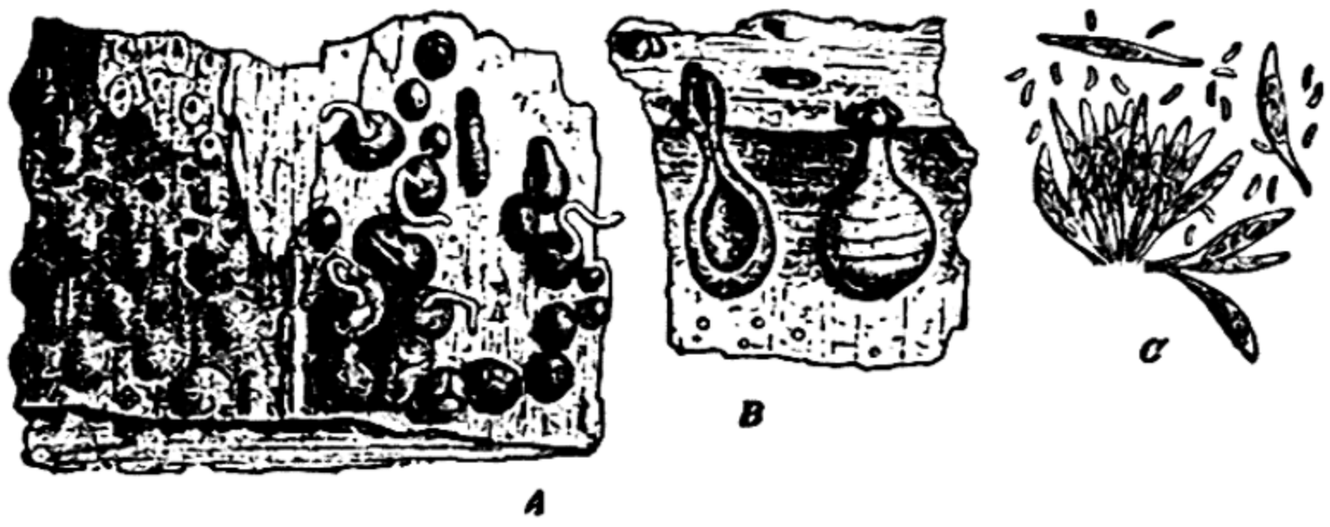


FIG. 207.—Valsa. *A*, habit sketch; *B*, perithecia; *C*. asci. After Tulasne.

V. leucostoma (Pers.) Fr.[22, 229, 280] Stroma strongly convex, 2–3 mm., whitish and granular within, outer layer coriaceous; perithecia immersed; asci fusoid-clavate, subsessile, 35–45 x 7–8 μ; spores biseriate, allantoid, hyaline, slightly curved, 9–12 x 2–2.5 μ.

Conidia (=Cytospora rubescens); stromate, erumpent, reddish; conidia allantoid, 4 μ. On pome and stone fruits throughout Europe, Australia and America causing the disease known as "dieback." The fungus was studied by Rolfs [279, 334] who worked out its life cycle.

V. oxystoma Rehm. occurs on Alnus in Europe;

V. (Eutypa) caulivora Rehm. affects Hevea.

V. ambiens Fr. is on the apple in Europe.

V. (Eutypella) prunastri (Pers.) Fr. is the cause of serious diseases of apples, plums, etc., in England.

V. (Eutypa) erumpens Mas. is reported as a wound parasite in the tropics on Ficus, and cacao.

Diaporthe Nitschke (p. 277)

Stroma very variable, usually definite; perithecia membranous subcoriaceous, generally pale-cinereous within, with a cylindric or filiform beak; asci fusoid; spores fusoid to subelliptic, 2-celled,

hyaline, appendaged or not; paraphyses none. Conidia=Phoma, Cytospora, etc.

D. taleola (Fr.) Sacc.

Stroma cortical, definite, depressed, pulvinate, 2–4 mm., covered; perithecia few, 4–10, buried, their ostioles converging, erumpent in a small light-colored disk; asci cylindric, 120–140 x 10–12 μ, spores elliptic, uniseptate, constricted, with setaceous appendages, 15–22 x 8–9 μ.

It causes canker on oak, killing the cortex over large areas. A year later the cushion-like stromata appear. The mycelium penetrates both wood and bark, probably entering through wounds.

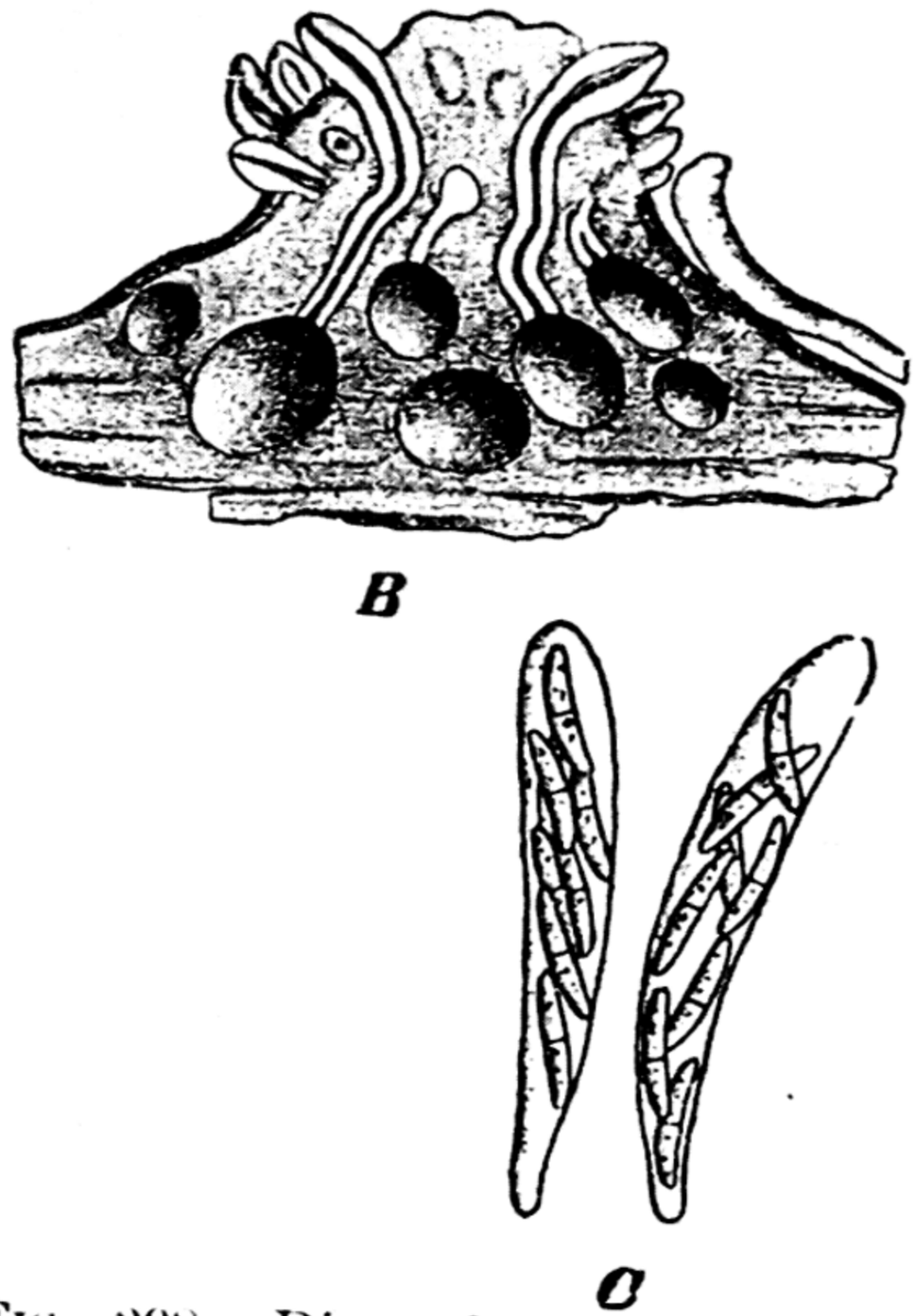


FIG. 208.—Diaporthe. *B*, stroma, in section; *C*, asci. After Tulasne.

D. albocarnis E. & E. on Cornus is destructive.

D. ambigua and **D. sarmentella** are on pear and hop, **D. strumella** on a wide range of hosts, in conidial form as Phoma.

Melanconidaceæ (p. 223)

A small family of less than two hundred species contains only four parasitic genera.

Stroma pulvinate, sunken; perithecia sunken in the stroma, the mouth erumpent; asci cylindric or clavate; paraphyses present.

KEY TO THE GENERA OF Melanconidaceæ

Spores 1-celled, hyaline
- Spores ellipsoid or short-fusiform. . . . . 1. **Cryptosporella,** p. 280.
- Spores elongate-cylindric, curved. . . . . 2. **Cryptospora.**

Spores 2-celled
- Spores hyaline
  - Conidia in pycnidia; 1-celled, hyaline. . 3. **Valsaria.**
  - Conidia not in pycnidia, dark brown. . 4. **Melanconis,** p. 281.
- Spores brown. . . . . 5. **Melanconiella.**

Spores more than 2-celled
  Spores hyaline
    Spores elongate, multicellular. . . . . 6. **Calospora,** p. 280.
    Spores fusiform, multicellular. . . . . 7. **Holstiella.**
  Spores brown
    Spores elongate, multicellular; asci
      8 or 4-spored. . . . . 8. **Pseudovalsa,** p. 281.
Spores long-cylindric, very large, asci
  1-spored. . . . . 9. **Titania.**

Calospora Saccardo

One species, **C. vanillæ** Mas., reported as causing a Vanilla trouble,[283] is perhaps identical with Glœosporium vanillæ C. & M.

Cryptosporella Tulasne (p. 279)

Stroma valsoid, pustuliform, covered; perithecia embedded, subcircinate, with converging necks united in an erumpent disk; asci cylindric to globoid; spores elongate, cylindric, hyaline, 1-celled.

C. anomala (Pk.) Sacc.[240, 284]

Pustules prominent, 2–5 mm., erumpent; penetrating the wood and generally having a thin black crust beneath them, disk convex or slightly depressed, cinereous to black; perithecia crowded, deeply embedded in the stroma, often elongate, ostioles scattered, black; asci short, broad, fugaceous; spores hyaline, elliptic, simple, 7–8 μ.



FIG. 209.—C. anomala. 31, stroma and perithecia; 32, an ascus; 33, spores. After Humphrey.

Common on hazel and filbert in America, causing the destruction of the tops while the roots remain alive.

C. viticola Sh.[324]

Pycnidia (=Fusicoccum) with labyrinthiform chambers, ostiolate but frequently rupturing. Spores hyaline, continuous, of two forms in the same cavity. 1. Subfusoid, 7.5 x 2–5 μ. 2. Long, slender, curved, 18–30 x 1–1.5 μ. Perithecia buried in irregular pulvinate

stromata, beak exserted; asci 60–72 x 7–8 μ; paraphyses slender, septate, wavy; ascospores subelliptic, hyaline, continuous, 11–15 x 4–6 μ. Fig. 210.

The conidial stage was described by Reddick as the cause of necrosis of grape vines [325] though he has since stated that the amount of damage due to this disease is not so great as at first thought.

The ascigerous form in pure culture in the hands of Shear [324] gave rise to the typical conidial form, identical with that grown from pure cultures of the pycnospores.

Melanconis Tulasne (p. 279)

Stroma valsoid, seated in the substratum, partially erumpent; perithecia clavate, immersed, with long cylindric beak; asci cylindric, long-clavate, 8-spored; spores ellipsoid to elongate, hyaline.

About twenty species; chiefly saprophytes.

M. modonia Tul. in its conidial form (=Fusicoccum perniciosum) causes a serious disease of the chestnut in Europe.[326, 345]

Pseudovalsa longipes (Tul.) Sacc. is parasitic on oak.

Diatrypaceæ (p. 223)

Stroma effused or pulvinate, built of thick hyphæ, under the peridium, at length erumpent, bearing both asci and conidia or present only with the conidia; perithecia sunken in the stroma or superficial, ostiolate; asci usually thickened apically; 4 to 8 or many-spored; spores usually continuous, small, cylindric, curved.

About one hundred seventy-five species.

One parasitic genus occurs on cherry and plum.

Key to Tribes and Genera of Diatrypaceæ

Stroma absent from ascosporic stage.	I. Calosphærieæ.
Asci 8 (rarely 4)-spored	
Spores 1-celled.	1. Calosphæria, p. 282.
Spores 2-celled.	2. Cacosphæria.
Asci many-spored.	3. Coronophora.
Stroma present in the ascosporic stage.....	II. Diatrypeæ.

Calosphæria. Tulasne (p. 281)

Perithecia astromate, free or on the inner bark, scattered or clustered, ostiole more or less elongate; asci clavate, fasciculate; spores small, cylindric, curved, hyaline, continuous; paraphyses longer than the asci, stout lanceolate, evanescent.

About thirty-five species chiefly saprophytes.

C. princeps Tul.

Perithecia on the inner bark in orbicular or elliptic groups, generally densely crowded, globose, smooth and shining, necks long,



FIG. 210.—Cryptosporella viticola. Asci and paraphyses. After Shear.

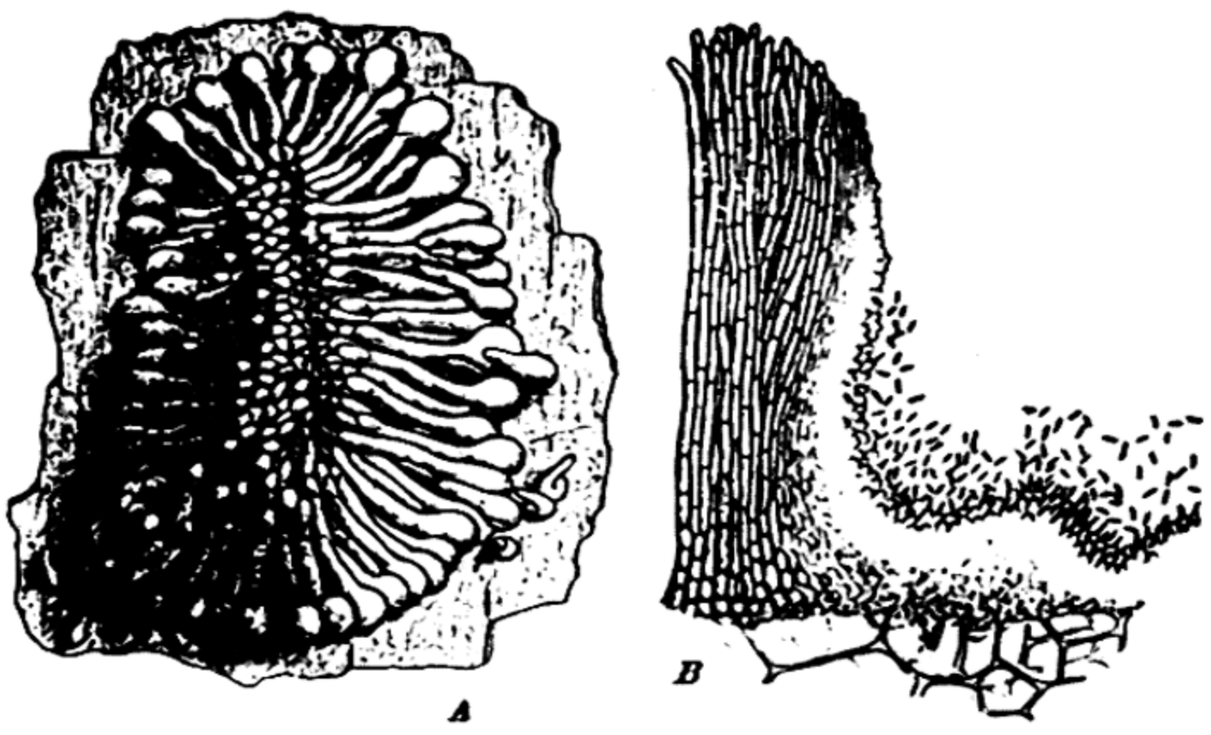


FIG. 211.—Calosphæria princeps. *A*, group of perithecia; *B*, conidial stroma. After Tulasne.

decumbent, flexuose, cylindric, erumpent; asci 12–26 x 4 μ, spores 5–6 x 1–5 μ.

On plum, cherry, peach and even pomaceous trees.

Melogrammataceæ (p. 223)

Stroma usually pulvinate, rarely effused, hemispheric, subperidial then erumpent and more or less superficial; perithecia sunken in the stroma; conidia occur in acervuli on the surface of the young stromata, or in pycnidia.

A small family of about one hundred twenty-five species, only one genus of which contains important pathogens.

Key to Genera of Melogrammataceæ

Spores 1-celled
  Spores roundish ellipsoid, asci long fusiform. . . . . 1. **Gibelia.**
  Spores ellipsoid or ovate, asci clavate. . . . 2. **Botryosphæria,** p. 283.
Spores 2 or more-celled
  Spores with cross walls only
    Spores 2-celled
      Spores hyaline
        Paraphyses present. . . . . 3. **Endothia.**
        Paraphyses absent. . . . . 4. **Myrmæciella.**
      Spores brown. . . . . 5. **Myrmæcium.**
    Spores more than 2-celled, ellipsoid to filiform
      Spores hyaline many-celled. . . . . 6. **Sillia.**
      Spores hyaline 3-celled. . . . . 7. **Melanops,** p. 284.
      Spores brown. . . . . 8. **Melogramma,** p. 284.
  Spores muriform. . . . . 9. **Berlesiella.**

Botryosphæria Cesati & de Notaris

Stroma pulvinate, black; perithecia at first sunken in the stroma, remaining so or becoming more or less prominent, usually small, globose, ostiole inconspicuous, papilliform; asci clavate; spores elliptic to oval, hyaline, continuous; paraphyses present.

B. ribis G. &. Dug.[285]

Stromata black, more or less pulvinate, outer surface botryose, 1–4 mm. in diameter, usually 2-3 mm., and surrounded by the fissured periderm, regularly scattered or in more or less definite, longitudinal rows or elongated stromata. Perithecia somewhat

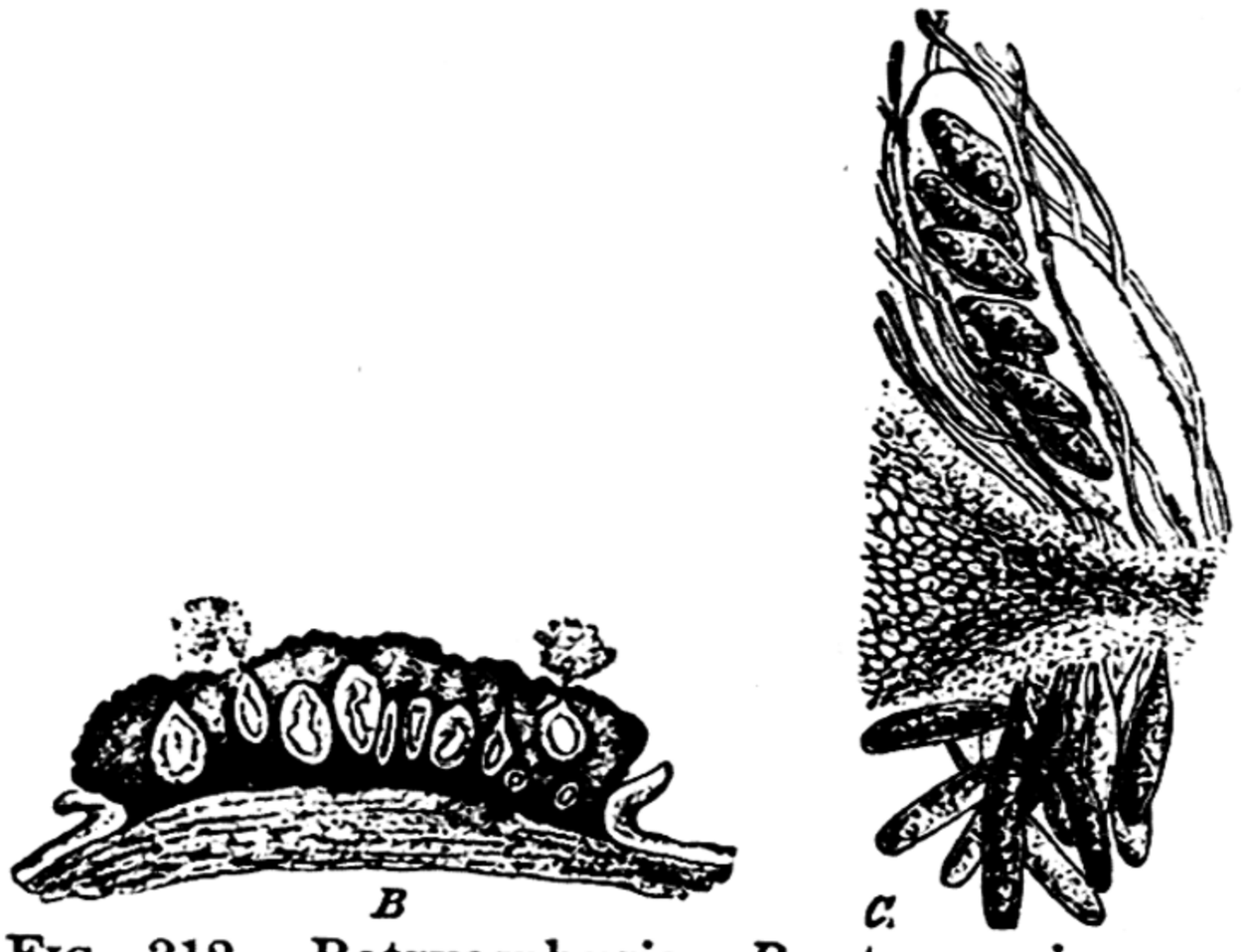


FIG. 212.—Botryosphæria. *B*, stroma in section; *C*, part of perithecium and pycnidium in section. After Tulasne.

top-shaped, with papillate ostioles and usually projecting, sometimes practically superficial. Few to many in a stroma and usually interspersed among pycnidia; 175–250 μ in width. Asci clavate, 80–120 x 17–20 μ, and with numerous filiform paraphyses. Spores fusoid, continuous, hyaline, 16–23 x 5–7 μ.

Pycnidia of the compound stylosporic form, Dothiorella, are borne in the same or similar stromata; spores fusoid, continuous, hyaline, 18–31 x 4.5–8 μ. Pycnidia of the simple stylosporic form, Macrophoma, are embedded in the outer bark under the much-raised primary cortex of young shoots, depressed globular, 175–250 mm. wide; spores fusoid, hyaline, continuous, 16–25 x 4.5–7.5 μ.

The cause of a blight of canes of currants.

The fungus was first noted in sterile form by Fairchild.[286] Its history was first fully worked out by Grossenbacher & Duggar.[285] Extensive inoculation experiments and pure culture studies definitely established its pathogenicity.

B. dothidæ Ces. & d. Not. causes epidemics of disease among cultivated roses.[22]

B. gregaria Sacc. is injurious on willows in Europe.[292]

Melanops Fuckel (p. 283)

Stroma lens-shaped, black; perithecia sunken; asci elongate, 8-spored; spores elongate, 3-celled, hyaline; paraphyses elongate, brown.

According to Shear,[346] the conidial stage of some members of this genus is a Sphæropsis which is indistinguishable from S. viticola and S. malorum.

Melogramma henriquetii Br. & Cav. is parasitic on cork oak.

Xylariaceæ (p. 224)

Stroma variable, usually free but often more or less sunken in the matrix, either upright and often branched or horizontal, effused, crustaceous, pulvinate, globose or hemispheric, black or becoming black, usually woody or carbonous; perithecia peripheral, immersed, leathery or carbonous, black; asci cylindric or cylindric-clavate, 8-spored; spores continuous, brown or black, fusiform or ellipsoid, paraphyses present or absent.

A family of over five hundred species.

Key to Genera of Xylariaceæ

Stroma encrusted, shield-form, globose or hemispheric, without a sterile base. . . .	I. **Hypoxyleæ.**
Conidial layer beneath the surface of the stroma, erumpent.	1. **Nummularia,** p. 285.
Conidial layer free from the first	
Stroma encrusted	
Spores 1-celled.	2. **Bolinia.**
Spores 2-celled.	3. **Camarops.**
Stroma discoid to hemispheric, encrusted together	
Young stroma fleshy, covered by conidia, at length carbonous. . .	4. **Ustulina,** p. 286.
Stroma carbonous or woody from the first	
Stroma without concentric layers.	5. **Hypoxylon.**
Stroma with concentric layers. . . .	6. **Daldinia.**
Stroma erect, simple or branched, clavate or cylindric, with a sterile base.	II. **Xylarieæ.**

Most of these genera are saprophytic on wood or bark.

Nummularia Tulasne

Stroma orbicular, cupulate or discoid, becoming black, marginate; perithecia monostichous, peripheral, immersed; asci cylindric; spores subelliptic, continuous, dark.

The genus contains forty species. Only one is recorded as injurious.

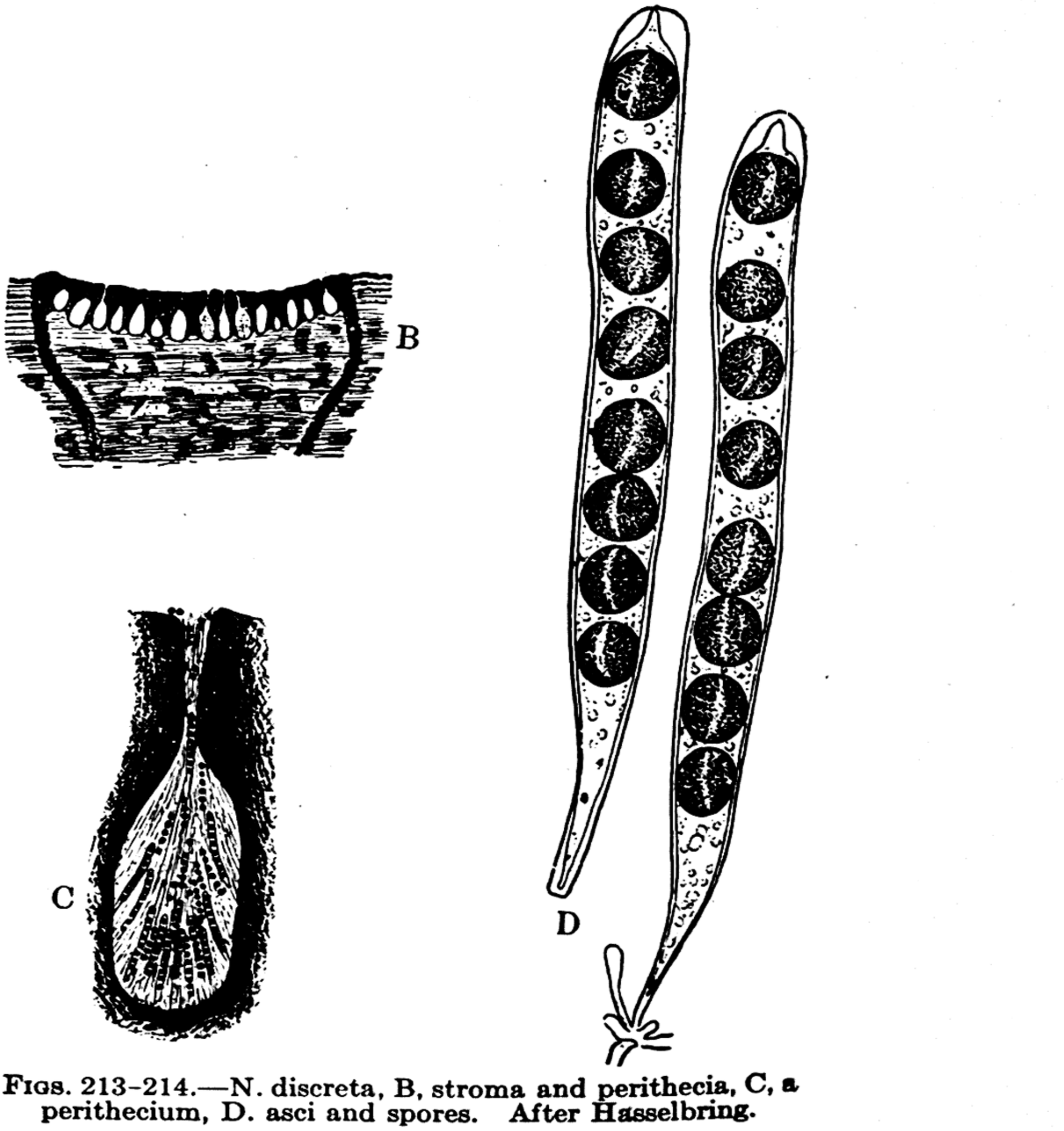
N. discreta (Schw.) Tul.

Stroma erumpent, orbicular, 2–4 mm., cupulate, with a thick raised margin; ovate, cylindric, nearly 1 mm. long, abruptly contracted above into a short neck; asci 110–120 x 10–12 μ; spores subglobose, nearly hyaline, then opaque, 10–12 μ; paraphyses filiform.

This fungus is usually a saprophyte but has been reported by Hasselbring as a serious parasite on the apple in Illinois.[287]

The mycelium grows more rapidly in the wood than in the bark,

attacking first the parenchyma cells and medullary rays. The young stromata appear under the bark bearing when young small unicellular conidia. The stromata later turn hard and black and



FIGS. 213–214.—N. discreta, B, stroma and perithecia, C, a perithecium, D. asci and spores. After Hasselbring.

in the upper layers bear numerous flask-shaped perithecia with long necks, Figs. 213–214.

Ustulina Tulasne (p. 285)

Stroma superficial, subeffuse, rather thick, determinate, at first clothed with a pulverulent cinereous conidial hymenium, finally rigid, carbonous, black, bare and generally more or less hollow;

perithecia immersed, large, papillate-ostiolate; asci pedicellate, 8-spored; spores ovoid-fusiform; paraphyses present.

A genus of about ten species, chiefly saprophytes.

U. zonata Lev. is the cause of the commonest root disease of tea and is common also on Hevea.

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BASIDIOMYCETES (p. 64)[1, 2, 7, 13, 19, 22, 25, 26, 27, 45, 47, 48, 49, 50, 53, 56, 59, 60]

This class is distinguished from all others by its **basidium,** which typically is a sporophore bearing on its distal end short stalks, the **sterigmata,** usually four, on which are borne spores, basidiospores, one on the tip of each sterigma, Fig. 215. In the great majority of genera the basidia are typical and are clearly recognizable as such.

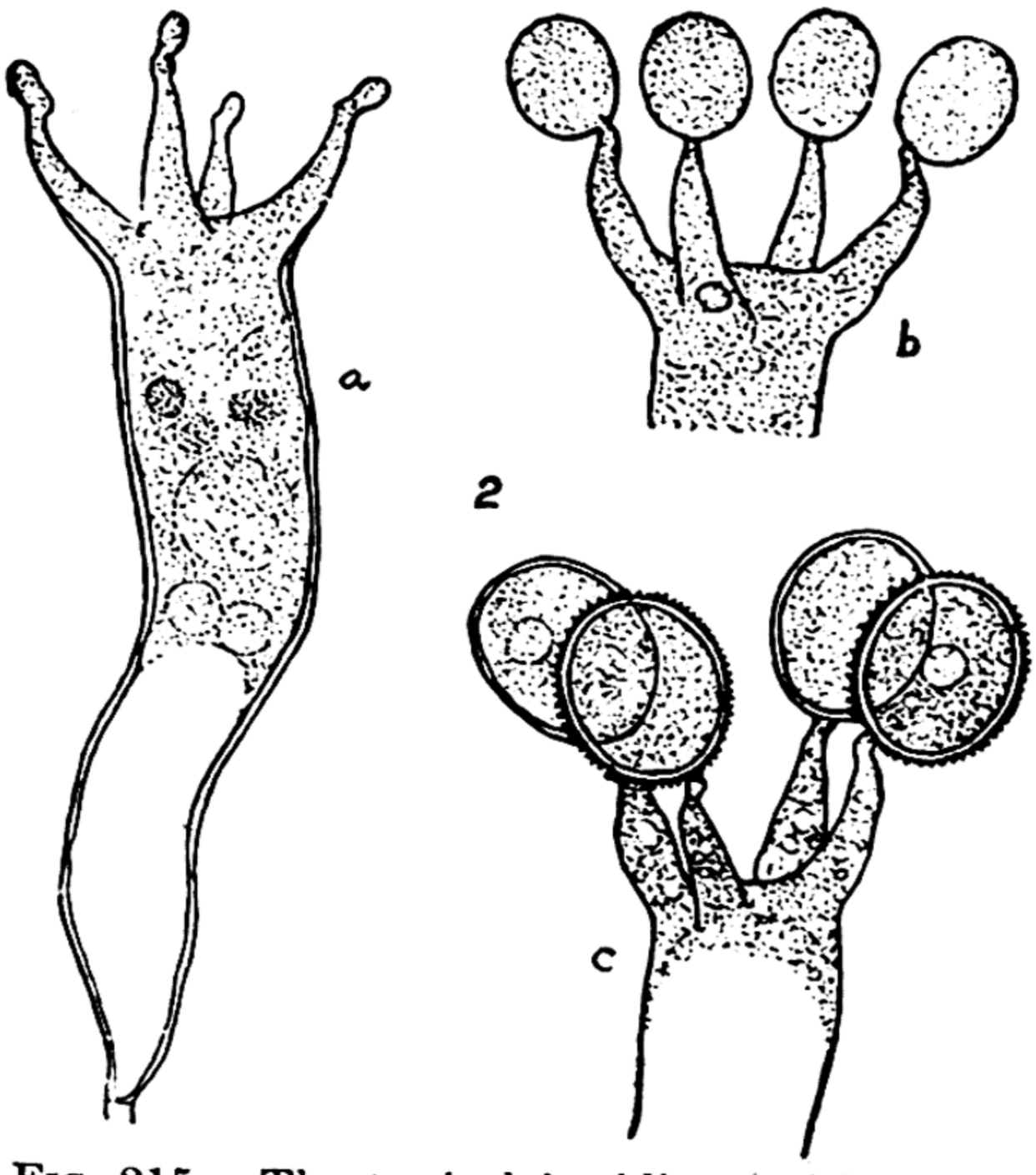


FIG. 215.—The typical basidium with sterigmata and spores in different stages of development. After De Bary.

In many of the lower basidiomycetes the basidia deviate somewhat from the typical form. Thus in the Hemibasidii, the smut fungi, the basidia are not typical in that they always arise from chlamydospores not directly from the mycelium, Figs. 217, 231, and that they may produce more than the normal number of four sporidia and these often from lateral, not terminal sterigmata.

The basidia in the large group of rust fungi are also atypical. The mycelium of the Basidiomycetes is septate and branched and is always well developed. It is often found invading cells several meters from the sporogenous structures and frequently weaves together to form rhizomorphs.

Peculiar cell connections known as clamp connections, or knee joints, Fig. 287, are often found. The basidia in many genera a

borne on large complex sporophores composed of the mycelial threads interwoven to form a false parenchyma. The spores may germinate by tubes or by budding.

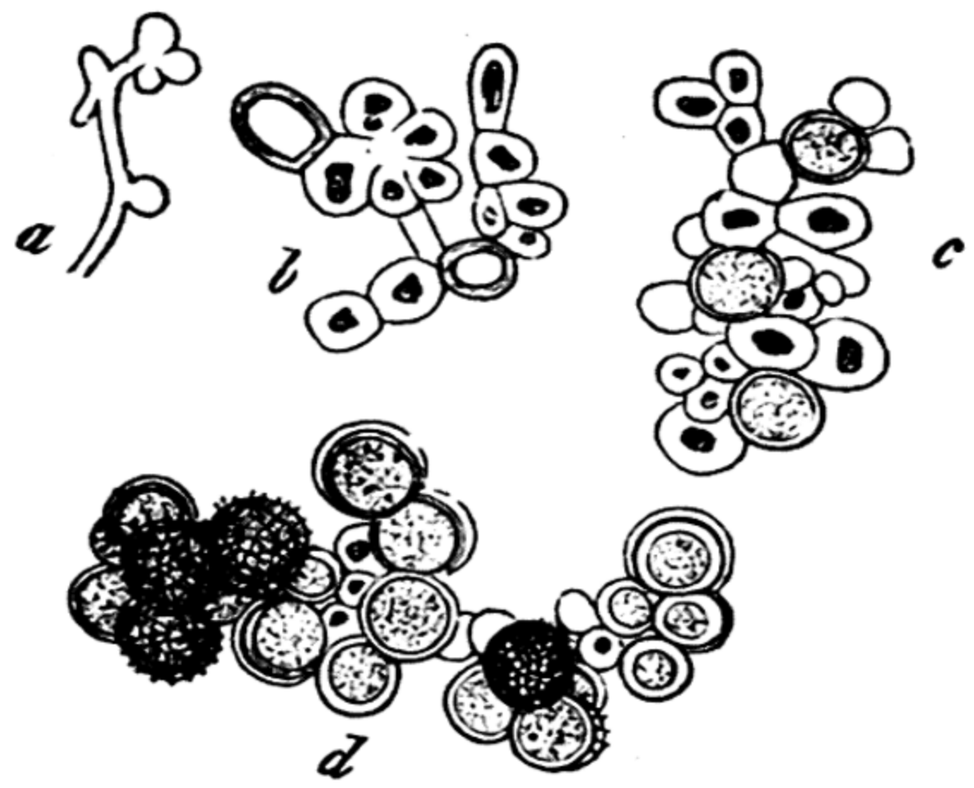


FIG. 216.—Ustilago spores showing development. After De Bary.

Typical sexuality seems entirely wanting, even rudimentary or vestigial sexual organs, certainly recognizable, have not been found. The group is supposed in this regard, to represent the results of extreme simplification; the sexual organs to have long ago disappeared and the simple nuclear fusions that now exist to serve functionally as fertilization.

KEY TO THE SUBCLASSES OF Basidiomycetes

Chlamydospores at maturity free in a sorus, produced intercalary, from the mycelium; basidiospores borne on a promycelium and simulating conidia..... 1. **Hemibasidii,** p. 299.

Chlamydospores absent or when present borne on definite stalks

Basidia septate, arising from a resting spore or borne directly on a hymenium..... 2. **Protobasidii,** p. 323.

Basidia nonseptate, borne on a hymenium..... 3. **Eubasidii,** p. 393.

Hemibasidii

The Hemibasidii contain one order.

Ustilaginales [45, 47, 124, 126–129, 131, 137]

Parasitic fungi, smut producers, mycelium consisting of hyaline, somewhat septate, branched, mostly intercellular filaments, practically limited to the interior of the host; at maturity often

disappearing partially or wholly through gelatinization; fertile mycelium compacting into masses and giving rise to numerous chlamydospores formed from its contents. Conidia rarely develop on the exterior of the host. Sori prominent, usually forming dusty or agglutinated spore-masses that break out in definite places on the host or more rarely remain permanently embedded in the tissues. Spores (chlamydospores) light to dark colored, single, in pairs, or in spore-balls, the latter often composed in part of sterile cells.

The Ustilaginales are all parasites on higher flowering plants. The vegetative mycelium is mostly inconspicuous and is often

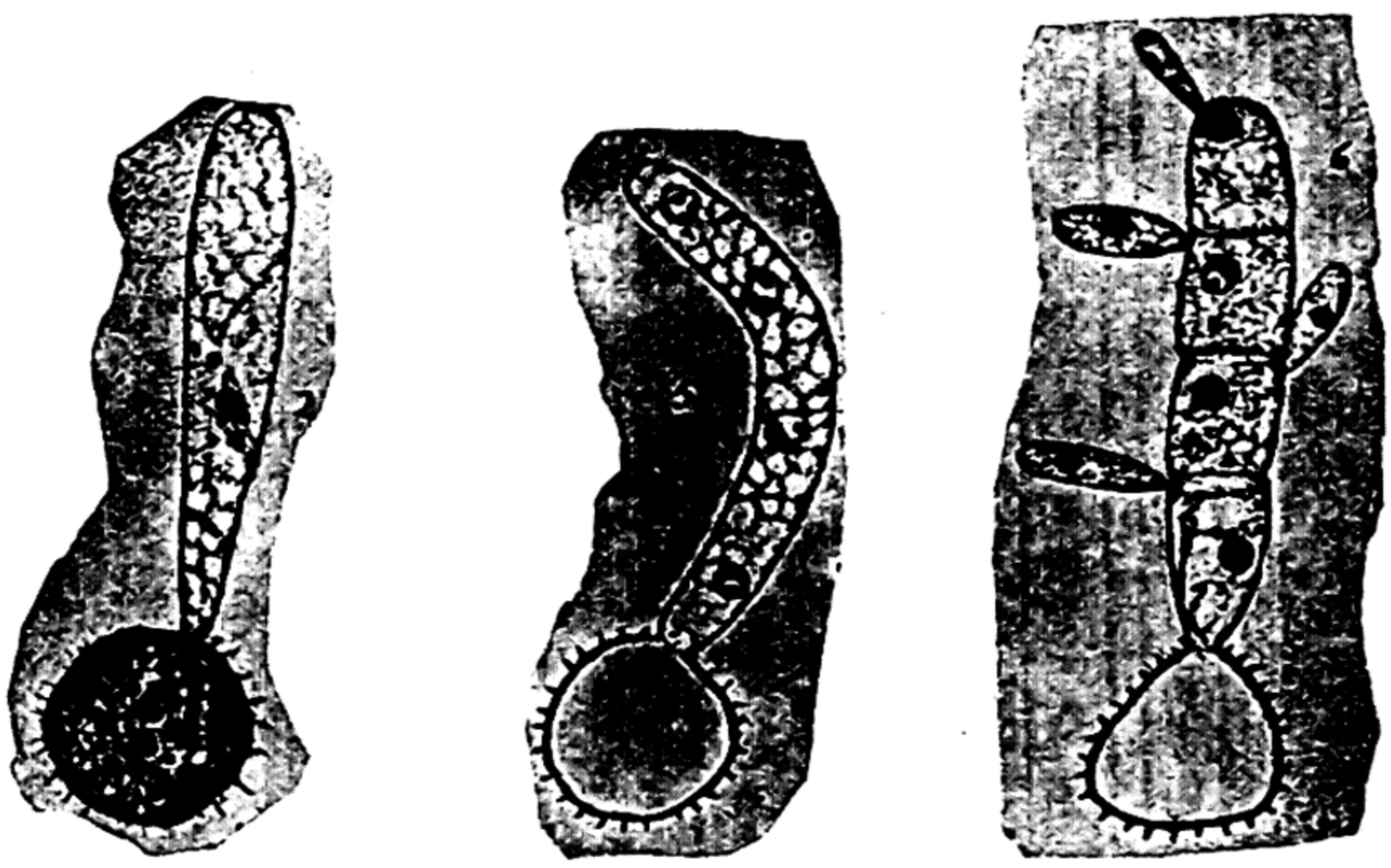


FIG. 217.—Ustilago. 2, promycelium with nucleus in mitosis; 5, with 4 nuclei; 6, with conidia. After Harper.

distributed very widely in the host plant without giving external evidence of its presence until time of spore formation. It sends variously formed botryose or spherical haustoria into the host cells. At time of maturity of the fungus, the mycelium develops in great abundance at certain special places in the host, often in the ovary, leading to the development of large mycelial structures in the place of the host tissue.

The chlamydospores develop directly from the vegetative mycelium; new and numerous transverse cell-walls are formed; the resulting short cells swell, round off and become coated with a gelatinous envelope. This later disappears and the spores develop a new, thick, usually dark, double wall which is variously marked.

The chlamydospores may be simple or compound, fertile or in part sterile and are variously shaped and marked as described in the genera below.

The chlamydospores may germinate at once or after a more or less protracted rest interval. In germination in water or nutrient solution (manure water, etc.) a short tube is protruded, the promycelium, this differing in character in the two families, Figs. 217, 231. From the promycelium of most species there develop conidia, (often called **sporidia**) 1–12 or even more. The promycelium is regarded as homologous with the basidium of the other basidiomycetes and the conidia as basidiospores.

The conidia in suitable nutrient solutions often undergo repeated and indefinite budding closely simulating yeast cells in appearance. Fusion of conidia is not uncommon.

Fig. 218. Conidia finding lodgment in suitable plant parts under suitable environmental conditions give rise to infection. The points at which infection can occur are very diverse with different species and will be considered under the separate species below.



FIG. 218.—Ustilago. 17, conidia fusing; 19, promycelial cells with fusion tube, apical cell disorganizing. After Harper.

The vegetative cells are binucleate in Tilletia, multinucleate in the Ustilaginaceæ.[1,139] The young chlamydospores were shown by Dangeard [2,115] in the case of Doassansia, Entyloma, Ustilago and Urocystis to be binucleate. These two nuclei, according to Dangeard, later fuse rendering the mature spore uninucleate. In germination the one nucleus passes into the promycelium, then divides mitotically Fig. 217, 2. A second division gives four nuclei (Fig. 217, 5) the spore nuclei.[4]

In the fusions of smut conidia Federly has found an accompanying nuclear fusion, in salsify smut, while Lutman finds similar fusion in the conjugating promycelial cells of oat smut.[3]

Whether or not these nuclear fusions represent a sexual act is a much controverted point.

There are according to Clinton about four hundred species in America.[5, 204]

Key to Families of Ustilaginales

Promycelium usually with sporidia lateral at septa	1. **Ustilaginaceæ**, p. 302.
Promycelium with clustered terminal sporidia	2. **Tilletiaceæ**, p. 314.

Ustilaginaceæ

Sori usually forming exposed dusty or agglutinated spore-masses. Germination of chlamydospores by means of septate promycelia which give rise to terminal and lateral sporidia or else to infection-threads.

Key to Genera of Ustilaginaceæ

Spores single	
Sori dusty at maturity	
Without definite false membrane	1. **Ustilago**, p. 303.
With false membrane of definite fungous cells	2. **Sphacelotheca**, p. 310.
Sori agglutinated at maturity	
Firmly agglutinated into conspicuous tubercular nodules	3. **Melanopsichium.**
Developed around a central columella (rarely dusty)	4. **Cintractia.**
Spores chiefly in pairs	
Sori agglutinated (on leaves)	5. **Schizonella.**
Sori dusty (inside peduncles)	6. **Mykosyrinx.**
Spores in balls of more than two	
Sori dusty or granular	
Spore-balls often evanescent; spores olive-brown or black-brown	7. **Sorosporium**, p. 312.
Spore-balls rather permanent; spores yellowish or reddish, with markings only on free surface	8. **Thecaphora**, p. 313.
Spore-balls quite permanent; spores adhering by folds or thickenings of outer coat	9. **Tolyposporium**, p. 313.

Sori agglutinated
Spore-balls (variable) composed of thick-walled spores..... **10. Tolyposporella.**
Spore-balls with peripheral spores and central sterile cells..... **11. Testicularia.**

Of these genera numbers three to eleven inclusive occur on unimportant plants. Among them are: Polygonum, Rynchospora, Psilocary, Cyperus, Carex, Luzula, Juncus, Fimbrystylis, Cissis; various unimportant grasses, members of the Carduaceæ, Fabaceæ, Nyctaginaceæ, Amarantaceæ, Cyperaceæ, Dracenaceæ, and Eriocaulaceæ. The most important genera are Ustilago and Sphacelotheca.

Ustilago (Persoon) Roussel (p. 302)

Sori on various parts of the hosts, at maturity forming dusty spore masses, usually dark colored; spores single, produced irregularly in the fertile mycelial threads which early entirely disappear through gelatinization, small to medium in size; germination by means of a septate promycelium producing only infection-threads or with sporidia formed terminally and laterally near the septa; sporidia in water usually germinate into infection-threads but in nutrient solutions multiply indefinitely, yeast-fashion.

About two hundred species, seventy-two of which are given by Clinton [5] as occurring in America. Besides the species discussed below many others occurring upon grasses or other plants of minor value are omitted.

U. avenæ (Pers.) Jens.[24, 116, 117, 124, 125]

Sori in spikelets, rarely in leaves, forming a dusty olive-brown spore-mass, about 6–12 mm. long by half as wide, usually rather completely destroying floral parts, eventually becoming dissipated; spores lighter colored on one side, subspherical to spherical though often elongate, minutely echinulate, 5–9 μ in length, widespread on oats.



FIG. 219.—U. avenæ, germinating in water. After Clinton.

The fungus was known by the name Ustilago as early as 1552

and was called U. avenæ in 1591. The species of Ustilago on oats, wheat and barley were considered identical until Jensen [8] showed that they are not intercommunicable. Wolff [6] showed that seedlings can be infected through the first sheath leaf. Brefeld [7] studying infection more closely found it to be accomplished by germ tubes from sporidia and that plants are free from infection after the growing leaves have pushed one centimeter through the sheath leaf. The mycelium, after infection, grows through the plant until blooming time when it seeks the ovaries and the enclosing glumes in which it forms a mycelial mass, which soon changes into spores. In nutrient solutions the conidia bud indefinitely, while on the host plant they produce infecting hyphæ.

Germination was first studied by Prévost.[9] It occurs readily in water, a well developed promycelium resulting in about twenty-four hours, Fig. 219. The sporidia are mostly narrowly elliptical. Fusion of sporidia is common. The promycelia are usually four-celled and occasionally branch, especially near the base. [118, 126

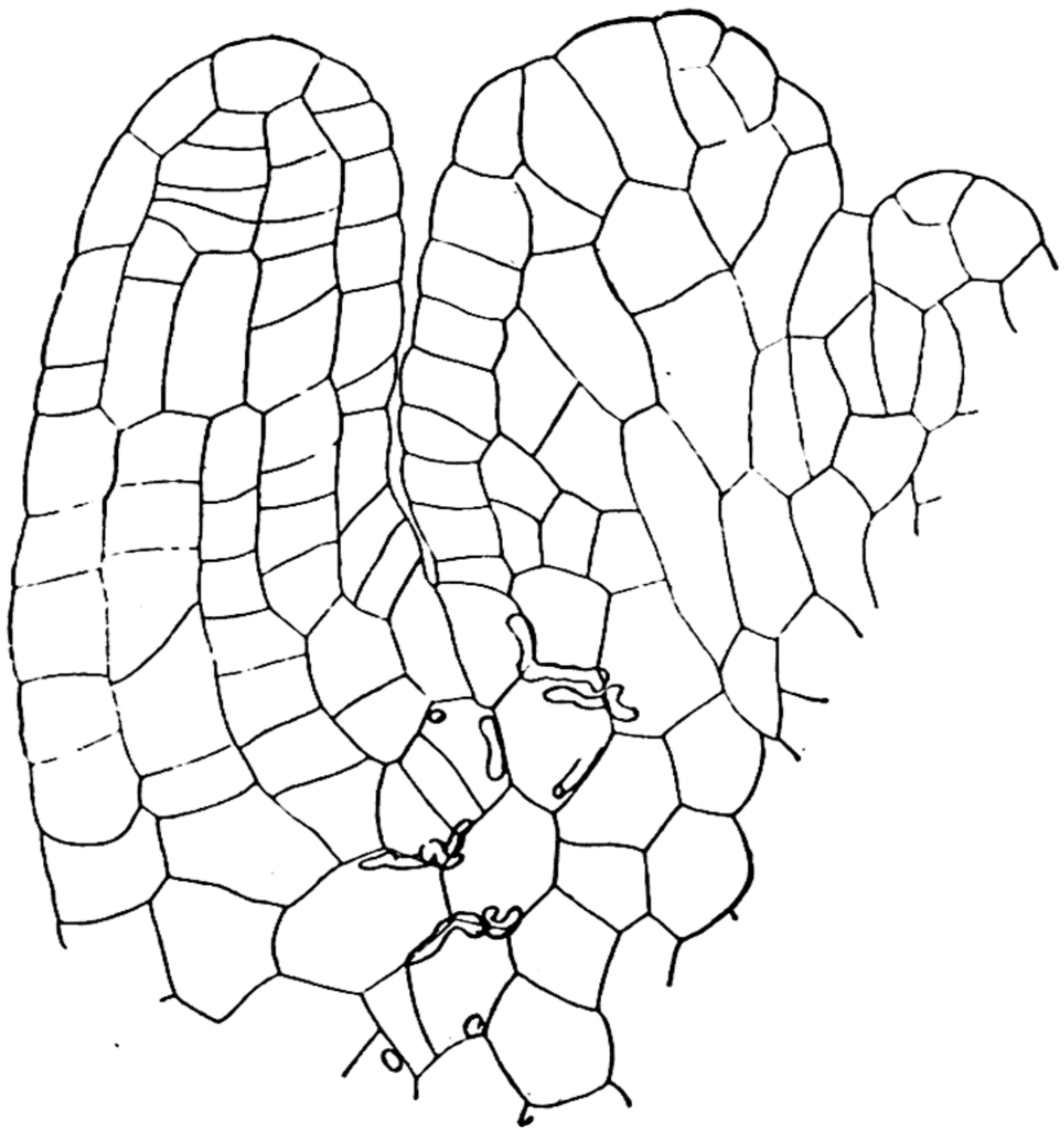


FIG. 220.—Growing point of the stem of barley. Much enlarged, showing smut mycelium. After Hecke.

U. crameri Körn.[24,

Sori in the spikelets, infecting all of the spike, ovate, about 2–4 mm. in length, chiefly destroying inner and basal parts; spores reddish-brown, chiefly ovoid to subspherical though occasionally more elongate and irregular, smooth, with usually pitted contents, chiefly 8–11 μ in length.

The promycelium is much branched but no sporidia are produced.

The smut commonly affects the ovaries of Panicum and Setaria. In America it has been collected on millet in several states.

U. crus-galli T. & E.[152]

Sori often encircling stems at nodes or at the juncture of the inflorescence, infecting both stem and leaves, prominent, often nodular, one to several centimeters in length, protected by a tough hispid membrane which upon rupture discloses an olive-brown dusty spore-mass; spores ovoid to spherical, occasionally more elongate, rather bluntly echinulate or even verruculose, chiefly 10–14 μ in length.

On Panicum crus-galli throughout the United States.

U. bulgarica Bub. is on Sorghum vulgare. European.

U. medians Bieden, on barley, is closely like U. hordei.[118]

U. scorzoneræ (A. & S.) Schr. on Scorzonera is very close to U. tragopogonis-pratensis.

U. sacchari Rab.[54]

Spore-mass black, spores globose or angularly globose, 8–18 μ in diameter, olive-brown or rufous, epispore thick, smooth.

On sugar-cane throughout the tropics, especially in the old world.

In Java this fungus has been reported as the cause of serious damage. Barrett observed it in Trinidad, where the damage was less extensive.

The leaves especially the young ones which have not yet separated from each other are the parts affected. From the upper part of the affected cane, as a rule, no secondary shoots arise, and those which do arise from the lower part become infected in their turn. The discolored whip-like structure at the end of an attacked cane becomes dusty and black and contains the spores of the fungus.

U. hordei (Pers.) K. & S.[24, 116, 134]

Sori in spikelets, forming an adhering purple-black spore-mass, about 6–10 mm. in length, covered rather permanently by the transparent basal parts of the glumes; spores lighter colored on one side, usually subspherical or spherical, smooth, 5–9 μ, the most elongate rarely 9–11 μ in length. Common on barley.

This was first recognized as distinct from the oat smut in 1591

by Lobelius.[10] Persoon in 1801 first gave a definitely recognizable description.[11] In 1888 the species was separated from the other smut on barley.[12]

The spores germinate freely in water by one, rarely two, tubes, usually 4-celled, and produce abundant sporidia; these increase by budding, produce germ tubes, or fuse with each other.

U. levis (K. & S.) Mag.[24, 116]

Sori in spikelets, forming a black-brown adhering spore-mass, sometimes small and entirely concealed by the glumes but usually evident and destroying inner and basal parts; spores lighter colored on one side, subspherical to spherical or rarely elongate, smooth, 5–9 μ, the most elongate rarely 11 μ in length.



FIG. 221.—U. levis, germination in modified Cohn's solution. After Clinton.

On oats throughout America and Europe, probably more common than records show as it is very difficult to distinguish from U. avenæ from which it differs chiefly in its smooth granular spores.

U. macrospora Desm.

Sori in leaves and glumes, generally showing as linear striæ, but often more or less merged, at first covered by the epidermis, but this later rupturing and disclosing black-brown dusty lines of spores; spores medium to dark reddish-brown, chiefly ovoid to spherical or occasionally somewhat irregular and elongate, coarsely verrucose, at circumference usually showing the projections as tinted blunt scale-like appendages, sometimes even semi-reticulate, 12–19 μ in length.

On various species of Agropyron in Europe and America.

U. nuda (Jens.) K. & S.[24, 116]

Sori in spikelets, forming a dusty olive-brown spore-mass, about 6–10 mm. long by half as wide, temporarily protected by a thin membrane which soon becomes dissipated leaving the naked rachis behind; spores lighter colored on one side, minutely echinulate, subspherical to spherical or occasionally elongate, 5–9 μ in length.

In Europe and America. This smut on barley is distinguishable from the covered smut, U. hordei, by its olive-green spore-mass and by its early shedding of spores. As a rule, each spikelet, ex-

cept the awn and rachis is entirely transformed into smut. In water and in nutrient solutions the spores germinate by a single promycelium, 1 to 3-septate, and often branched, but without sporidia. That infection is floral in loose smut of both wheat and barley was first shown by Maddox [13] and the fact was corroborated by Wakagawa,[14] Brefeld [15] and Hecke.[16, 17] The mycelium has been demonstrated in the embryo by Broili.[123]

The spores falling between the glumes germinate, penetrate the ovary wall, and into the growing point of the embryo. The mycelium here lies dormant until the seed germinates, when it grows, keeping pace with the growing point throughout the season and finally invading the ovaries to produce its spores.

The infection of the pistil, the penetration of the integuments and the nucellus and embryo sac was followed in microtome sections by Lang.[122] The embryo was reached by the mycelium some four weeks after infection of the pistil. In resting grains the mycelium is abundant in the scutellum as well as in all embryo parts except the roots.

Cross inoculation by Freeman and Johnson [18] from barley to wheat and the reverse gave negative results. The optimum time for infection has been determined as the period of full bloom.

U. perennans Rost.[124, 134]

Sori in spikelets, more or less destroying the basal and inner parts, sometimes even running down on pedicels, oblong, about 3–8 mm. in length, with dusty, olive-brown spore masses; mycelium perennial in perennial parts of host; spores chiefly subspherical or spherical, occasionally ovate to ellipsoidal, usually lighter colored on one side, more or less minutely echinulate, especially on the lighter side, 5–8 μ in length.

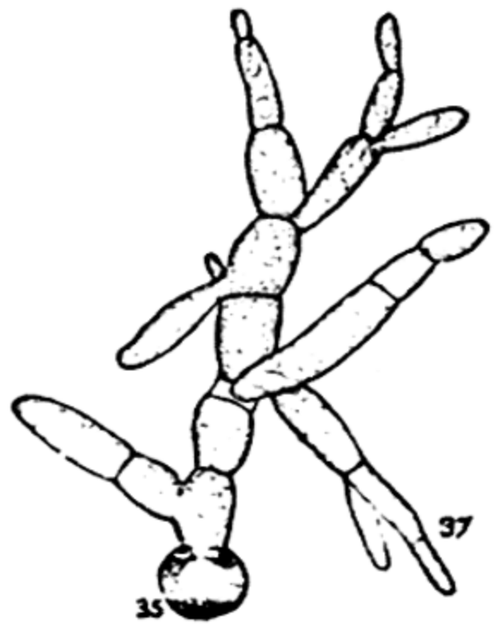


FIG. 222.—U. tritici, germination in modified Cohn's solution. After Kellerman and Swingle.

On the tall oat grass throughout its range.

U. rabenhorstiana Kühn occurs on several species of Panicum.

U. tritici (Pers.) Rost.[24, 116, 124, 125, 128]

Sori in spikelets, forming a dusty olive-brown spore-mass, about 8–12 mm. long by half as wide, usually entirely destroying floral

parts and eventually becoming dissipated and leaving behind only the naked rachis; spores lighter colored on one side, usually subspherical to spherical, occasionally elongate, minutely echinulate especially on the lighter side, 5–9 μ in length. On wheat wherever cultivated.

The smut mass is covered at first by a very delicate membrane. Infection is floral as described for U. nuda.

The spores germinate in water by a long 2 to 3, or even 6 to 7-septate, promycelium, often curved. In nutrient solutions the



FIG. 223.—U. zeæ, stages in spore development. After Knowles.

promycelium branches profusely but sporidia are few or are entirely absent.

U. zeæ (Beck.) Ung.[19, 21, 119–121, 133, 136, 142]

Sori on any part of the corn plant usually prominent, forming irregular swellings from a few millimeters to over a decimeter in diameter, at first protected by a sort of false white membrane composed of plant cells and semi-gelatinized fungous threads, soon rupturing and disclosing a reddish-brown spore-mass; spores ellipsoidal to spherical or rarely more irregular, prominently though rather bluntly echinulate, 8–11 μ the most elongate 15 μ in length.

The germination of the spores, which occurs but poorly in water, was first studied by Kühn [20] in 1857. In 1874 Kühn saw the penetration of the germ tubes through the epidermis of the corn plant. Brefeld showed that the spores germinate well in nutrient solutions and that secondary spores are formed; also that corn can be infected by the sporidia at any point on its surface above ground

when the tissues are soft and actively growing; and that infection is local on the host.[21]

It is now known that the chlamydospores are capable of germination without hibernation and that they remain viable one, two, perhaps more years. It was shown by Brefeld in 1895 that the chlamydospores produce conidia in the air freely. It is these, air-borne, arising from spores on the ground, manure, etc., which are chiefly responsible for infection. They must reach the plant on a susceptible part and under suitable conditions of moisture. The germ tubes from the conidia penetrate the epidermis, grow through or between the cells, Fig. 223, with an irregular mycelium which branches profusely and calls forth great hypertrophy of the surrounding host tissue. In sporing, the mycelium forms a great number of short, slender, irregular branches which make up a close tangled network in the diseased tissue. These slender branches swell, gelatinize, and portions of them round off as spores, Fig. 223.

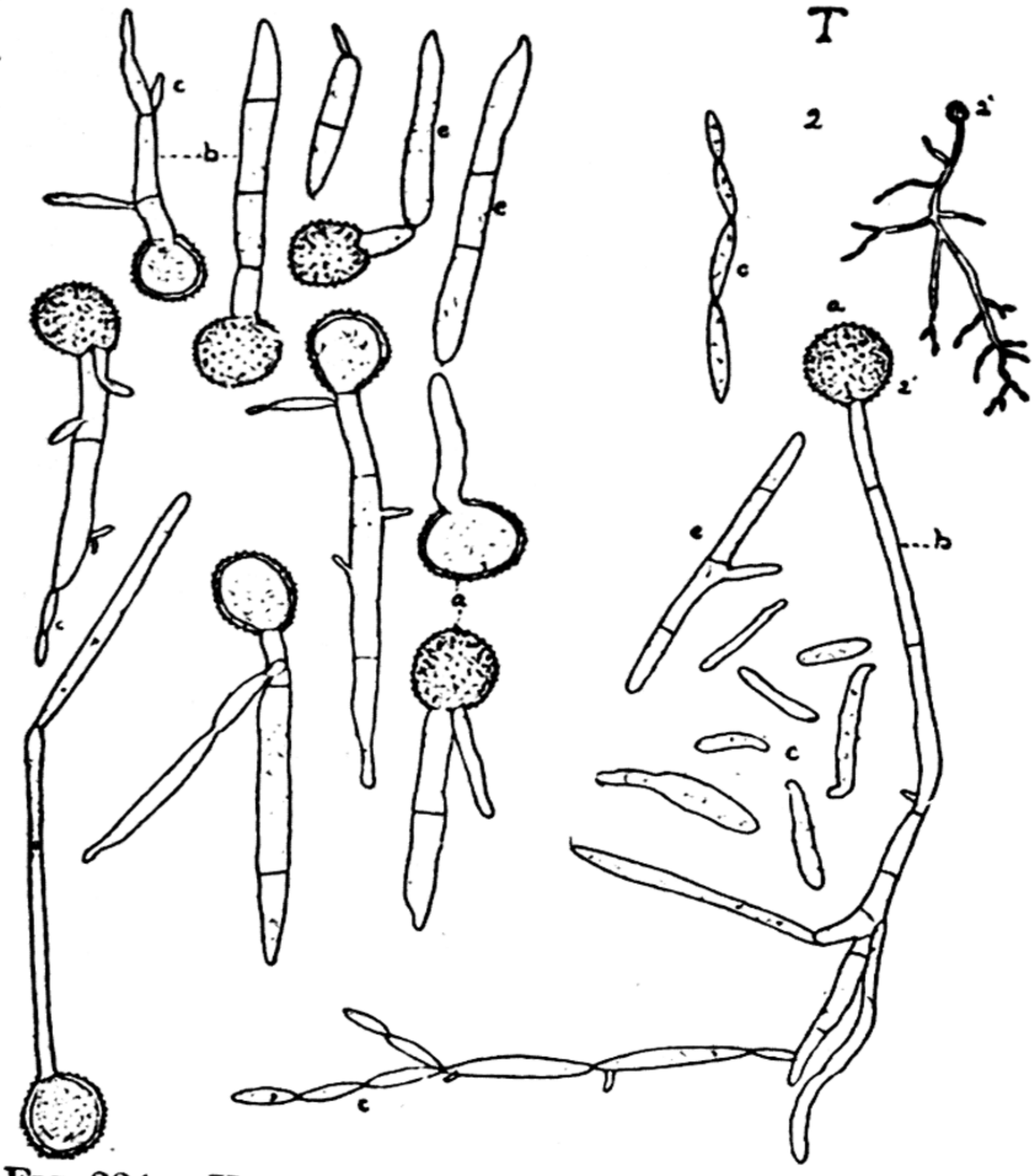


FIG. 224.—U. zeæ. 1, germination after three days in water; 2, similar but in air showing air sporidia. After Clinton.

U. striæformis (West.) Niess.[24, 15?]

Sori in leaves, sheaths and rarely in the inflorescence, from sheer to linear, often extending, apparently by terminal fruitings of several centimeters, also occasionally fusing laterally structure of the leaf at first covered by the epidermal cells which are round structured and dusty brown to black.

scattered and the leaves become shredded; spores usually ellipsoidal to spherical, occasionally irregular, prominently echinulate, chiefly 9–14 μ in length.

It appears to be perennial. The spores germinate sparsely. The promycelium is long, branched, septate, and produces no conidia.

On numerous species of grass, including red top, timothy and species of Poa and Festuca throughout Europe and America.

Species of less importance, not all found in America are:

U. schiriana Hem. which attacks bamboo; [22]

U. secalis Rab. is European on rye; possibly a Tilletia.

U. esculenta P. Hen. which causes swellings on Zizania which are eaten in the orient;

U. vaillantii Tul. in the sexual organs of the Liliaceæ;

U. panici-miliacei (Pers.) Wint. on Panicum miliaceum;

U. tragopogi-pratensis (Pers.) Wint. on the flowers of Tragopogon;

U. cruenta Kühn, widespread in Europe on sorghum;

U. violacea (Pers.) Fcl. on the anthers of various members of the Caryophyllaceæ;

U. tulipæ Wint. on tulips and related hosts;

U. vrieseana Vuill. on eucalyptus roots, a very doubtful species;

U. sphærogena Burr. on Panicum crus-galli.

The fungus described as U. fischeri Pers. from Italy on corn is a Sterigmatocystis as is also U. phœnicis Corda on date fruits and U. ficuum Reich on figs.

Sphacelotheca De Bary (p. 302)

Sori usually in the inflorescence, often limited to the ovaries, provided with a definite, more or less temporary, false membrane, covering a dusty spore-mass; and a central columella, usually formed chiefly of the host plant's tissues. The false membrane is composed largely or entirely of sterile fungous cells which are hyaline or slightly tinted, oblong to spherical, and usually more or less closely bound together; spores single, usually raddish-brown, Conidia formed somewhat centripetal manner as in Cintractia, spores are capable of germination as in Ustilago.

The fungus are described after Clinton for America. Of these

only three are of economic importance. By Engler and Prantl, the genus is not separated from Ustilago.

Sphacelotheca sorghi (Lk.) Cl.[23, 24, 128, 136, 144]

Sori usually in the ovaries or stamens forming oblong to ovate bodies 3–12 mm. in length (rarely fusing the very young spikelets into irregular forms), protected for some time by a false membrane upon the rupture of which the olive-brown spore-mass becomes scattered, leaving naked the distinct columella of plant tissue. The sterile cells of the membrane break up to some extent into groups, hyaline, oblong to subspherical, chiefly 7–18 μ in length; spores subspherical to spherical, smooth, contents often granular, 5.5—8.5 μ in diameter.

On Johnson grass and sorghum throughout the world. The young pistil and usually the stamens as well are displaced by the fungous mycelium, the two being often blended together. The spores germinate readily in water, either when fresh or a year old, showing papillæ in from three to ten hours. The promycelium is 2 to 3-septate and from the ends of one or more of its cells narrow tubes appear. These later fuse with the adjacent cell, forming the "buckle joints." Either infection tubes or sporidia may also arise from the promycelium. Infection is possible only with young plants.

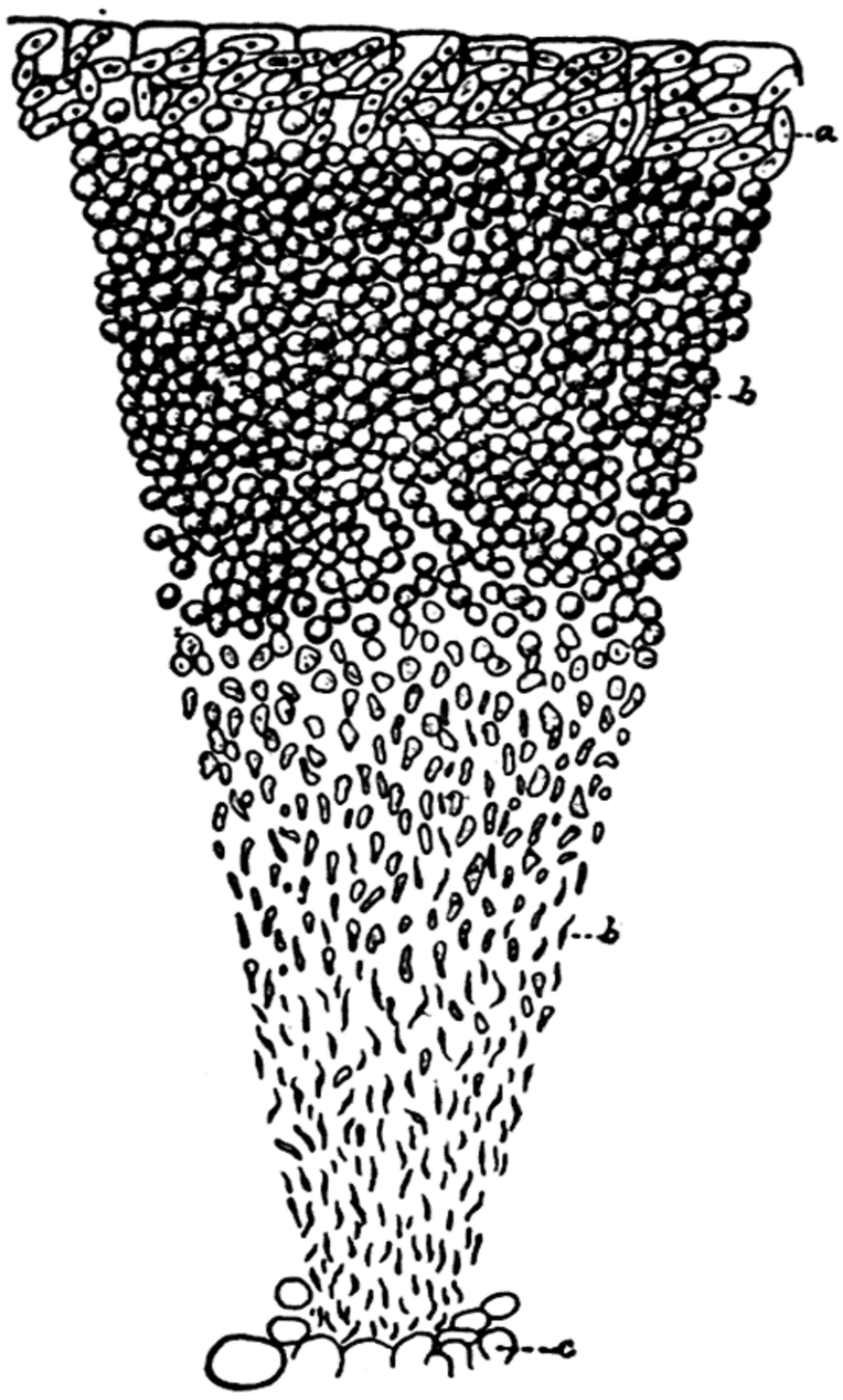


FIG. 225.—S. sorghi, cross-section through base of young infected body (ovary). *a*, false membrane of epidermal cells and sterile mycelium, *b*, mature spores, *b'*, immature spores, *c*, columella. After Clinton.

The mycelium in the host plant grows rapidly into long irregular, hyaline, thin-walled threads 2–4 mm. thick, which run through and between the cells. It is most abundant in the parenchyma, advancing especially through the pith region with the growth of the host. The young ovaries and stamens are eventually reached

and the mycelium there develops richly under the epidermis. The outer cells remain sterile and constitute the membrane; the inner gelatinize and develop into spores.

S. reiliana (Kühn) Cl.[24, 119, 136, 141, 126]

Sori very prominent forming irregular masses including more or less of the entire panicle, usually 5–15 cm. in length; often at first protected by the leaf-sheath. A whitish false membrane encloses the black-brown spore-mass and the ray-like remains of the peduncles or columellas. In time it becomes ruptured and the spores scattered. Sterile cells are also scattered in groups through the spore-mass, chiefly subspherical, 7–15 μ in diameter; spores somewhat opaque, chiefly subspherical to spherical or occasionally ovoid or slightly angled, minutely but abundantly verruculose, 9–14 μ in length.

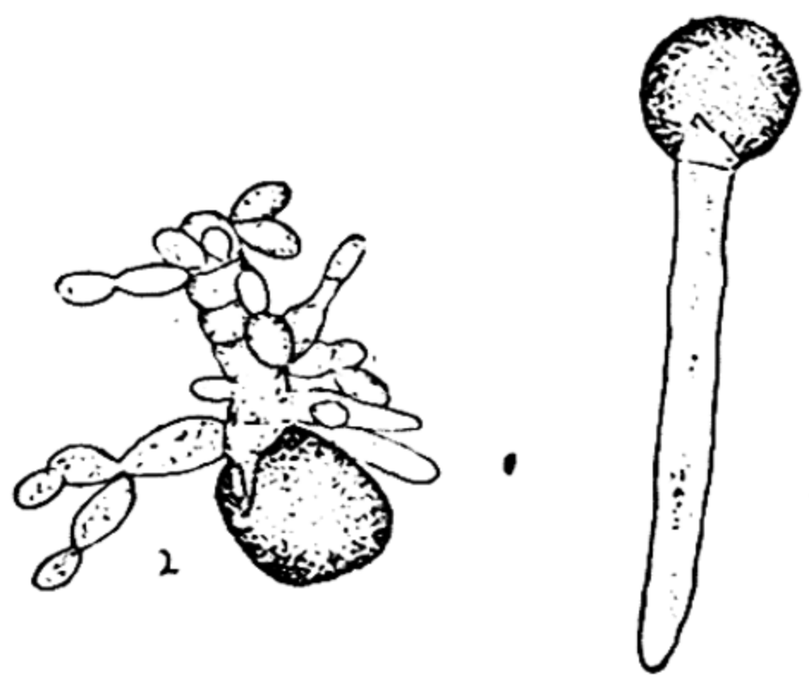


FIG. 226.—S. reiliana. Germination in water. After Hitchcock and Norton.

This is a cosmopolitan but comparatively rare form on corn, affecting the ovaries. It occurs also on sorghum. In germination a 3 to 4-celled, often branched, promycelium is formed and conidia are produced.

S. diplospora (E. & E.) Cl. is found on Panicum crus-galli and related grasses in the lower Mississippi Valley.

Sorosporium Rudolphi (p. 302)

Sori in various parts of the host, forming dusty, dark colored spore-masses; spore-balls of medium size composed of numerous fertile cells, often rather loosely united and frequently at maturity completely separating; spores usually olive or reddish-brown, of medium size; germination similar to that of Ustilago; sometimes with elongate germ thread and no sporidia.



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FIG. 227.—Sorosporium. Spore mass. After Dietel.

Several species are parasitic on the coarser range grasses. **S. consanguineum** E. & E., **S. everhartii** Ell. & Gall., and **S. ellisii** Winter, are probably the most important. **S. dianthi** Rab. is found on Dianthus.

Thecaphora Fingerhuth (p. 302)

Sori in various parts of the host, often as indefinite masses in the floral parts or forming rather firm pustules on the stem, at maturity with a dusty spore-mass; spore-balls composed of few to many fertile cells, of small to large size; rather permanently united; spores usually yellowish or reddish, smooth on contiguous sides but usually marked on the free surface; germination, so far as known, by means of a single sporidium at the tip of the elongate septate promycelium.

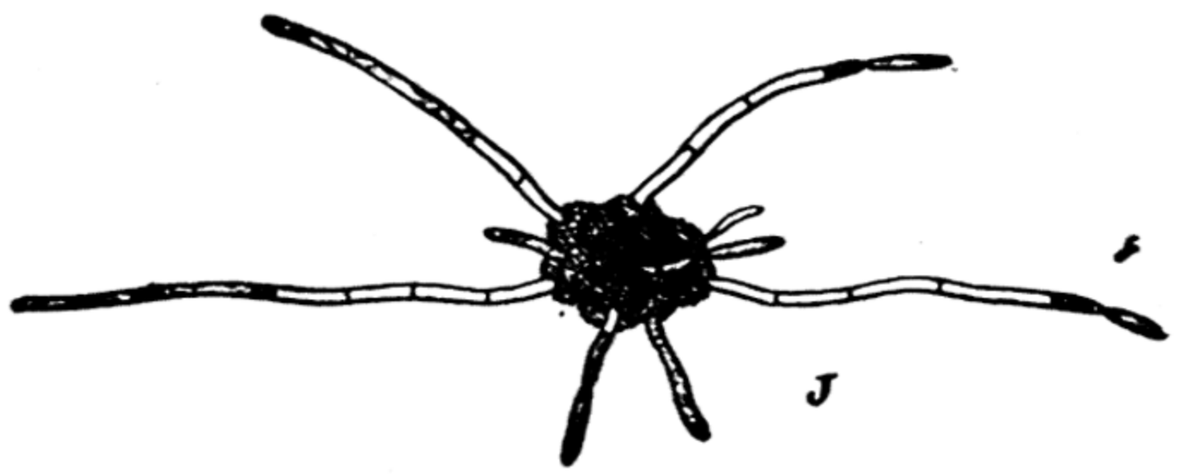


FIG. 228.—Thecaphora, spore ball germination. After Brefeld.

A small genus of slight economic importance.

T. deformans Dur. & M.[126, 129]

Sori in the seeds, showing when the legumes are broken open as reddish-brown, dusty spore-masses which destroy most of the seeds; spore-balls reddish-brown, ovoid to spherical, rather firm, composed of 3–25 (usually 7–12) spores, chiefly 27–60 μ in length; spores in optical section triangular to polygonal or when free irregular oblong, free surface with papillæ that sometimes vary to spiny processes, 15–25 μ, chiefly 15–20 μ in length.

On a large number of Leguminous hosts, including species of Vicia, Lathyrus, Lupinus, Trifolium, etc., in widely scattered regions of both the old and the new world.

Tolyposporium Woronin (p. 302)

Sori usually in the inflorescence, especially the ovary, forming granular spore-masses at maturity; spore-balls dark-colored, of numerous spores permanently united, germination about as in Ustilago.

A genus of about ten species.

T. bullatum Schr.[128, 154]

Sori in ovaries, infecting occasional ones, ovate, about 3–5 mm. in length, covered with a thin, greenish, smooth membrane, upon rupture of which the black granular spore-mass becomes scattered;

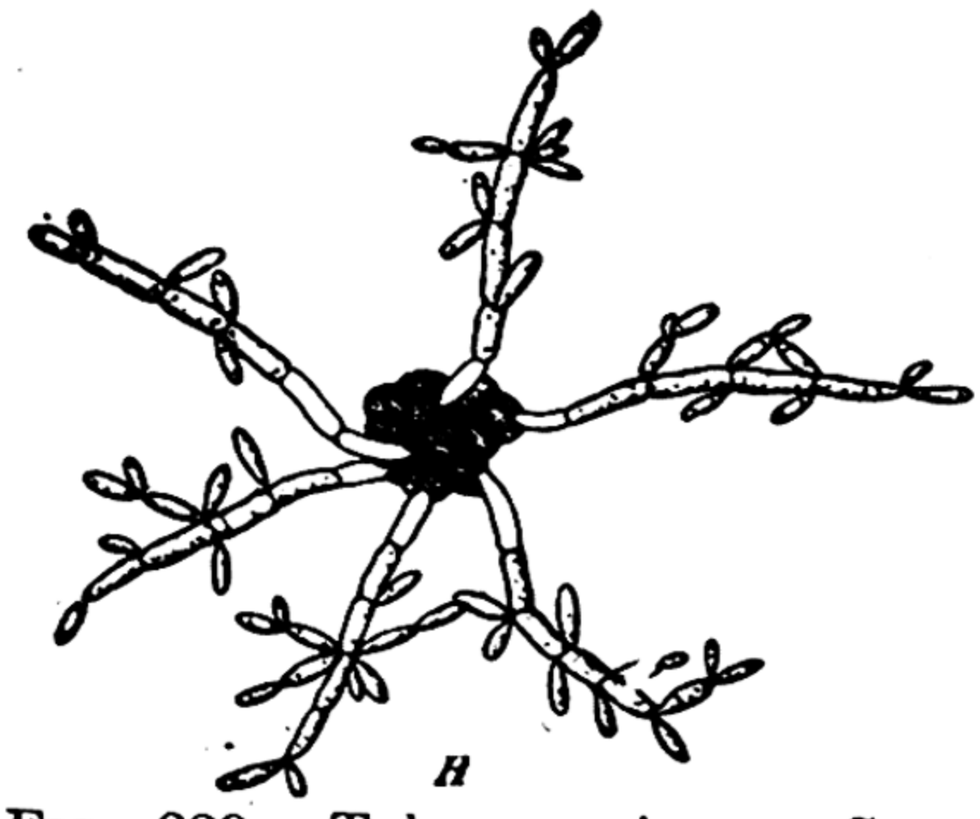


FIG. 229.—Tolyposporium. Spore ball germination. After Brefeld.

spore-balls black, opaque, oblong to spherical or polyhedral, usually containing one hundred or more firmly agglutinated spores, chiefly 50–180 μ in length; spores from nearly hyaline, to light reddish-brown, outer coat more or less folded in ridges, often spiny, ovoid to subspherical or polyhedral, chiefly 7–10 μ or rarely 12 μ in length.

On Panicum crus-galli in the United States east of the Rocky Mountains also in Europe.

T. filiferum and **T. volkensii,** occur on sorghum in Africa.

Tilletiaceæ (p. 302)

Sori either forming dusty erumpent spore-masses or permanently embedded in the tissues. Germination by means of a short promycelium which usually gives rise to a terminal cluster of elongate sporidia, that, with or without fusing in pairs, produce similar or dissimilar secondary sporidia or germinate directly into infection threads.

The American Tilletiaceæ embrace nine genera and about one hundred twenty-five species.

KEY TO GENERA OF Tilletiaceæ

Spores single
- Sori dusty at maturity
  - Spores without a conspicuous hyaline appendage ..... 1. **Tilletia,** p. 315.
  - Spores with an elongate hyaline appendage ..... 2. **Neovossia.**
- Sori permanently embedded in the tissues
  - Sori definite, small ..... 3. **Entyloma,** p. 320.
  - Sori indefinite, large ..... 4. **Melanotænium.**

Spores in balls
- Sori dusty; spore-balls with sterile cortex ..... 5. **Urocystis,** p. 318.

Sori rather permanently embedded in tissues	
Spore-balls without sterile cortex	
Spore-balls consisting entirely of dark-colored spores.	6. **Tuburcinia.**
Spore-balls consisting of light-colored spores	
Spore-balls with or without central sterile cells.	7. **Burrillia.**
Spore-balls with central network of filaments.	8. **Tracya.**
Spore-balls with sterile cortex.	9. **Doassansia,** p. 322.

Neovossia occurs on Phragmites; Tuburcinia on Convallariaceæ, Primula, Trientalis and Geranium in Russia; Burrillia on Limnanthemum, Echinodorus and Sagittaria; Tracya on Spirodela.

Tilletia Tulasne [140] (p. 314)

Sori in various parts of the hosts, usually in the ovaries, forming dusty spore-masses; spores single and usually formed singly in the ends of the mycelial threads which disappear more or less completely through gelatinization, germination usually by a short promycelium which bears a terminal cluster of elongate sporidia that in nutrient solutions, with or without fusing in pairs, may give rise to a considerable mycelium bearing secondary air-sporidia.

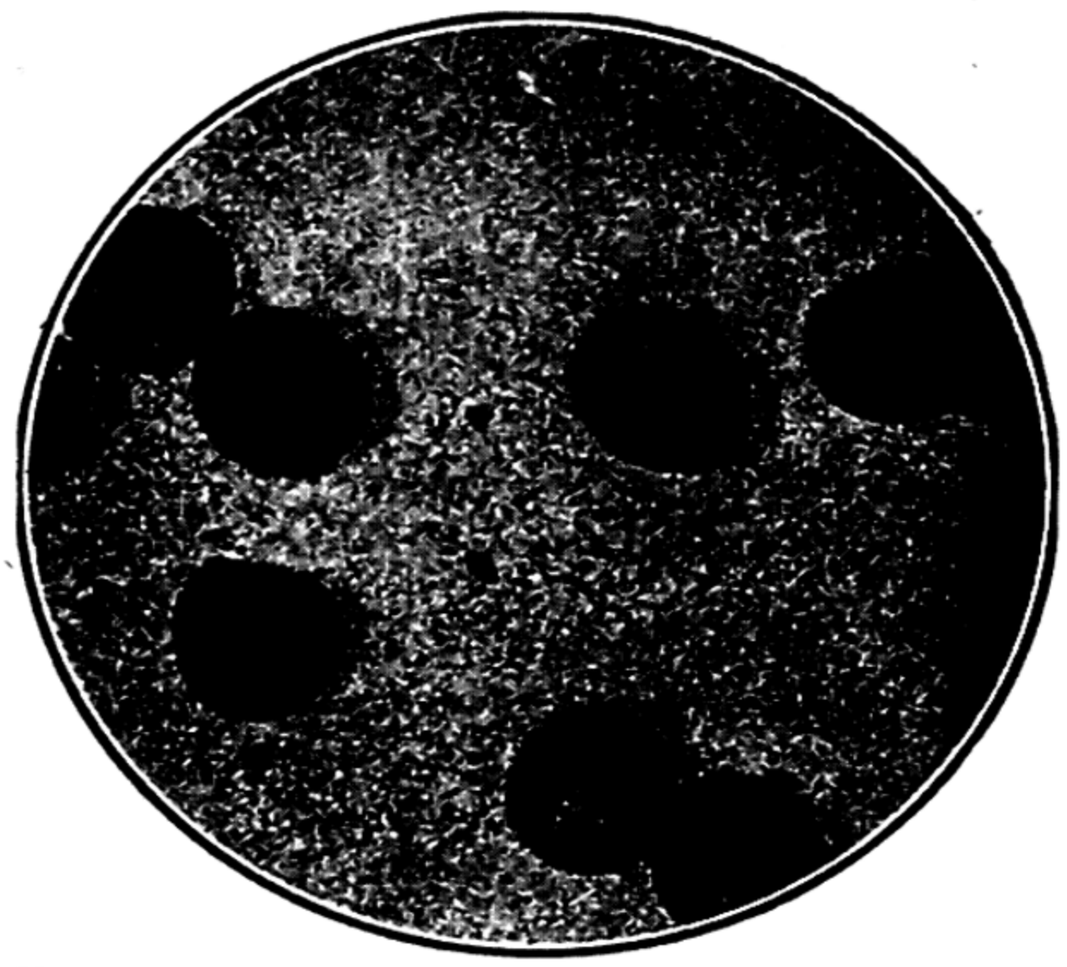


FIG. 230.—T. fœtens, spores. Photomicrograph. After Clinton.

The genus closely resembles Ustilago except in its larger spores and mode of germination.

Twenty-two American species are listed by Clinton. Only three are of economic importance.

T. pancicii Bub. & Ran. is reported on barley heads in Servia.[25]

T. glomerulata. Cocc. & Mor. is a doubtful species on alfalfa.

T. fœtens. (B. & C.) Trel.[24, 124, 125, 135]

Sori in ovaries, ovate or oblong, 5–8 mm. in length, more or less concealed by the glumes, all or only part of the ovaries of a spike infected; spores light to dark-brown, oblong to chiefly subspherical or spherical, occasionally somewhat angular, fœtid, especially when young, smooth, chiefly 16–22 μ, the most elongate rarely 28 μ in length.

On wheat wherever grown.

Kühn [20] found that infection occurs as in oats in the very young plants. From the infection point the mycelium approaches the growing point and follows the development of its host, sending its branches into each spikelet and finally into the growing ovules. Here it develops a close knot and in the ends of the threads and in the short branches the spores form. The spores germinate by a rather long, continuous, thick promycelium on the tip of which a crown of long slender conidia develops. The sporidia soon become arched and often fuse in pairs; they develop infection threads.

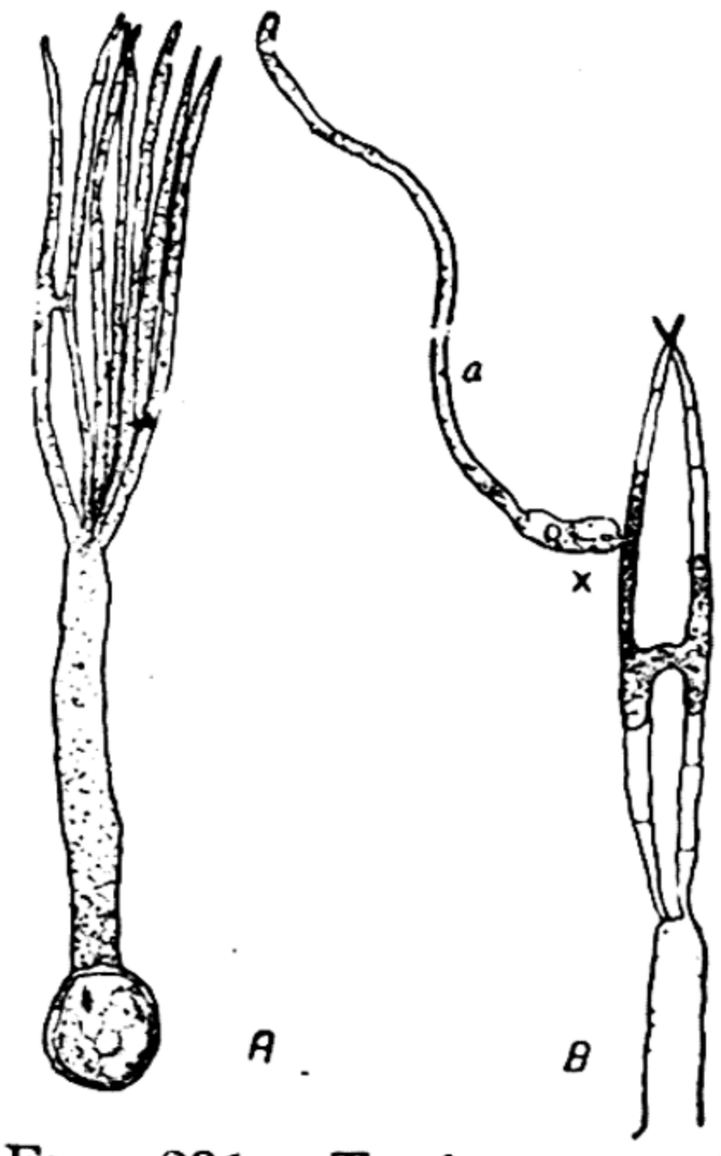


FIG. 231.—T. fœtens. *A*, germinating spore producing sporidia; *B*, Sporidia which have united. One has produced a secondary sporidium at X and this is sending out an infection thread. After Freeman and Stedman.

T. tritici (Beij.) Wint.[126]

Sori in ovaries, ovate to oblong, 5–8 mm. in length, more or less concealed by the glumes; sterile cells few, hyaline, subspherical, with medium-thin wall, smaller than the fertile cells which are chiefly subspherical, light to dark-brown, with winged reticulations about 1 μ high by 2–4 μ wide, and 16–22 μ in diameter.

On wheat everywhere.

Experiments have shown this distinct from T. fœtans which it closely resembles except for its reticulate spores.

T. texana Long: Cl.[129]

Sori in ovaries, ovoid or oblong, about 3–5 mm. in length, more or less hidden by enveloping glumes, forming a somewhat agglutinated light-reddish-brown spore-mass; sterile cells not very

numerous, hyaline, with very thick, often lamellate walls; fertile cells very light colored, orange-yellow appearing as if immature, chiefly subspherical or spherical, with prominent conical tubercles which extend out 2–3 μ to the hyaline envelope, chiefly 19–25 μ in diameter (including envelope.)

On Hordeum nodosum in Texas.

T. hordei Kcke is an Asiatic form on Hordeum.

T. secalis (Cda.) Kühn. occurs on rye in Europe.[138]

T. horrida Tak.[26, 121, 149]

Sori in the ovaries more or less destroying them, completely

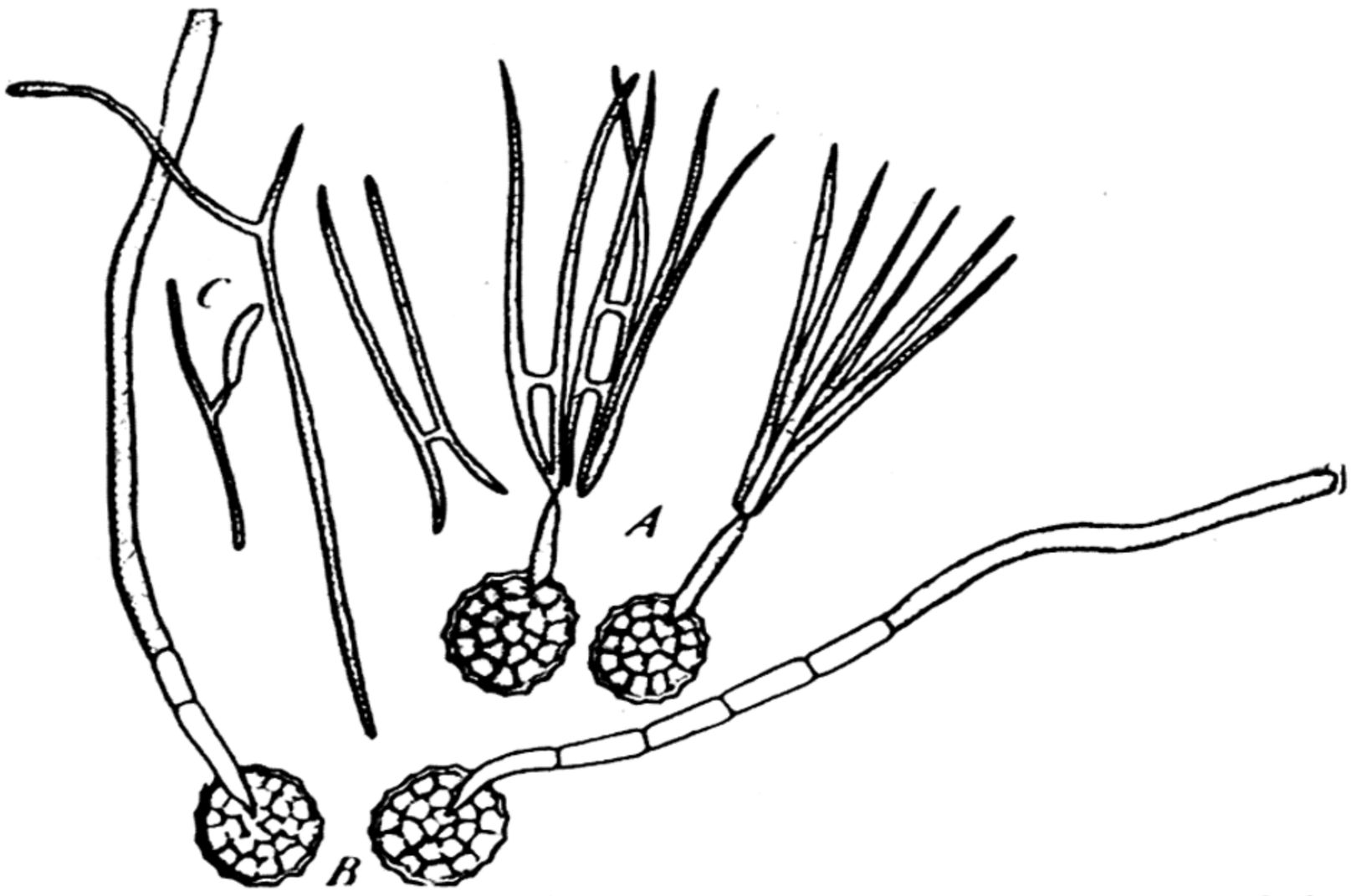


FIG. 232.—Tilletia tritici. *A*. Two spores germinated in moist air, promycelium and conidia, several of which have fused in pairs. Secondary conidia at *C*. *B*. Spores germinated in water, promycelia elongate, septate. The protoplasm passes over into the younger cells. After Tubeuf.

concealed by enveloping glumes; spores usually present in different stages of development, the mature spores almost opaque, chiefly subspherical to spherical, with very coarse hyaline or slightly tinted, somewhat curved, scales which show at the circumference of the spore as a band about 2–4 μ wide and on its top as polygonal areas 2–3 μ across; hyaline membrane more or less evident and often at one side in a short thread-like projection, 22–33 μ in length.

Cross sections of stems bearing smutted heads reveal the mycelium in the chlorophyll parenchyma between the fibrous tissue.[26]

On rice in America and Asia.

Urocystis Rabenhorst [143] (p. 314)

Sori usually in the leaves or stems, occasionally in other parts, producing dark-colored, usually dusty, spore-masses; spore-balls permanent, composed of an enveloping cortex of tinted sterile cells and usually one to several interior fertile cells; fertile cells generally dark-colored; germination often by a short promycelium which produces terminally-grouped sporidia; these give rise to similar secondary sporidia or to infection-threads.



FIG. 233.—Spore balls of U. cepulæ. After Thaxter.

Besides the forms discussed below, foreign species are listed on Anemone, Liliaceæ, Gladiolus, Primula, etc.

U. cepulæ Frost.[27, 28, 130, 146]

Sori in leaves, forming isolated pustules or affecting them for the greater part of their length and breadth, sometimes occurring at their bases, in the bulbs. Upon rupture of the covering membrane a dusty black-brown spore-mass appears; spore-balls ovoid to spherical, 17–25 μ in length; sterile cells tinted, ovoid to spherical, small, rather completely covering the spores, usually 4–8 μ in length; fertile cells reddish-brown, ovoid to spherical, usually 1, rarely 2 in a ball, chiefly 12–16 μ in length. On Allium.

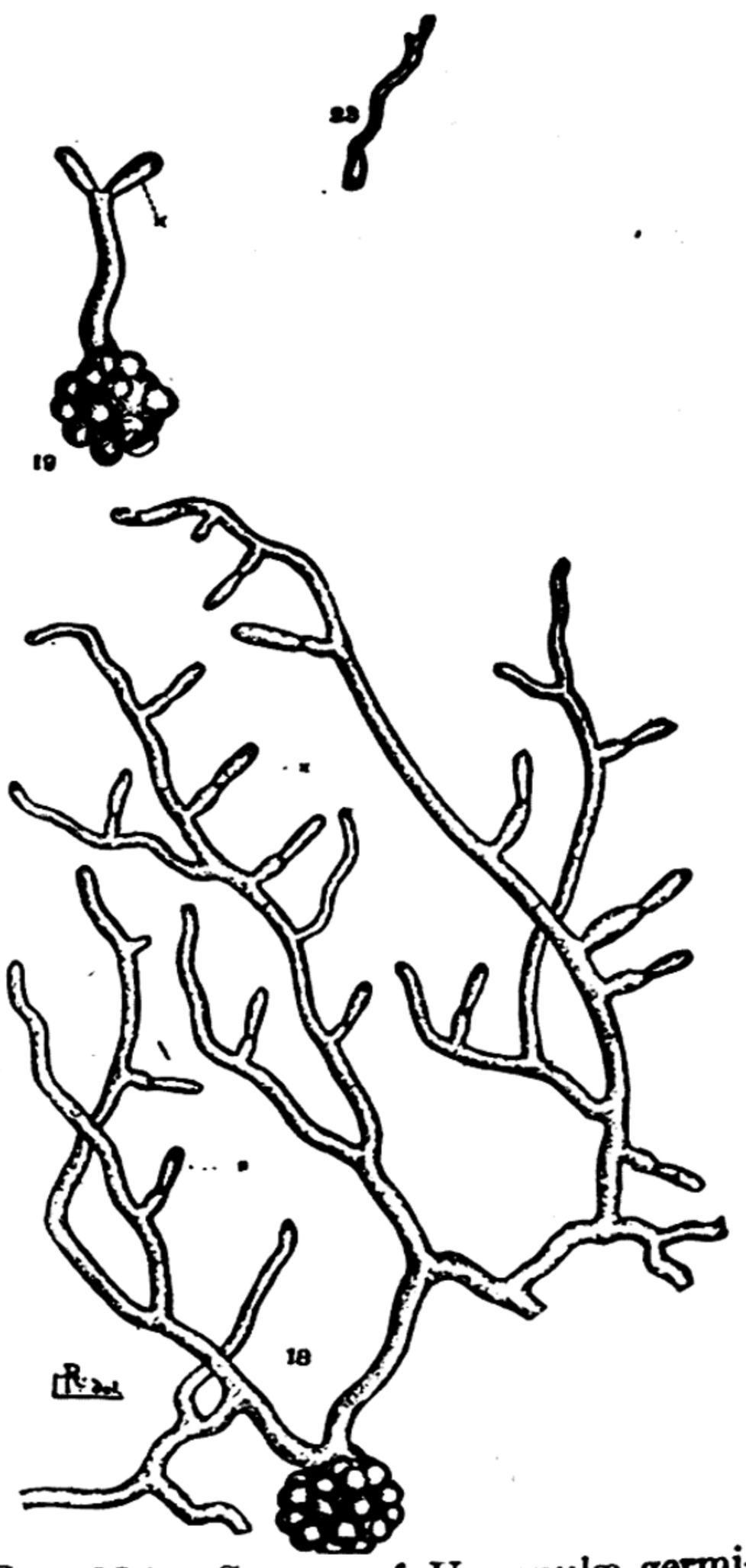


FIG. 234.—Spores of U. cepulæ germinating. x, sporidia; 23, germinating conidium. After Thaxter.

The first American description of the fungus was by Farlow [27] in 1876. A second thorough paper was from Thaxter in 1889.[28]

The mycelium grows between the host cells. At maturity lateral

outgrowths appear from the hyphæ at various points. One of these assumes a somewhat spherical form and matures to the fertile spore, while the other branch or branches grow around it, Fig. 235, branching and dividing into joints which eventually round off to form the sterile exterior cells. Spores are known to live in soil for at least twelve years.[28] A period of rest is necessary before they can germinate. In germination the central spore produces a single short hypha, commonly branched, on which the conidia are borne terminally and laterally. Fig. 234. Experiments by Thaxter indicate that infection is subterranean.



FIG. 235.—Successive stages in formation of spore balls. After Thaxter.

U. occulta (Wal.) Rab.[128, 151]

Sori in leaves, especially in the sheaths, culms and inflorescence, forming linear striæ usually of great length and often merged into a continuous stratum of dusty, reddish-black, spore-balls; spore-balls oblong to subspherical, 16–32 μ in length; sterile cells often incompletely covering the spores, hyaline or yellowish, subspherical to oblong, usually with distended and uniformly thickened walls; fertile cells reddish-brown, oblong to subspherical, often flattened, smooth, 1 to 4 in a ball, 11–18 μ in length.

On rye wherever cultivated, though not common in America.

The seat of spore formation is most often on the stems or sheaths, though all aërial parts of the plant are susceptible. In the vegetative parts the fungus is commonly found in the tissue between the vascular bundles.



FIG. 236.—Spore balls of U. occulta. After Thaxter.

U. violæ (Sow.) F. de W.[128, 143, 150]

Sori on stems, rootstocks, petioles and leaves forming prominent irregular swellings often several centimeters in length, rather permanently covered by the host tissues but upon rupture disclosing black-brown spore-masses; spore-balls reddish-brown, rather irregular, oblong to subspherical, chiefly 28–55 μ in length; sterile cells yellowish-tinted with age, 6–10 μ in length; fertile cells light reddish-brown, ovoid to spherical or polyhedral, chiefly 4–8 in a ball, mostly 11–15 μ in length.

On violets. In America it has been reported in Canada, Minnesota and Utah.

U. anemones (Pers.) Wint.[128] occurs on various species of Ranunculaceæ in both the old and new world.

U. agropyri (Preu.) Schr.[5]

Sori in various parts, commonly in leaves, forming striæ, which may be distinct or cover the surface of the leaf; at first lead-colored and protected by the epidermis but soon rupturing and scattering the reddish-brown spores; spore-balls oblong to subspherical, 16–32 μ in length; sterile cells hyaline to yellowish, oblong to subspherical, usually completely covering the fertile cells, outer wall thin and by collapsing giving a ridged effect to the covering; spores 1 or 2, rarely 3 or 4 in a ball, reddish-brown, oblong to subspherical, often flattened, smooth, 11–18 μ in length.

On Agropyron and some other coarse grasses throughout the United States and Europe.

U. colchici (Schl.) Rab.[143] On various species of Liliaceæ but not on hosts of economic importance in America.

U. italica Speg. probably not a true smut, is injurious to acorns, chestnuts and the seeds of the white fir.[29]

Species of less importance or non-American are:

U. gladioli (Req.) Sm. on Gladiolus;

U. ornithogali Körn. on Ornithogalum;

U. kemetiana Mag. in pansy ovaries;

U. primulicola Mag. on primrose flowers.

Entyloma De Bary [132, 145] (p. 314)

Sori usually foliar, generally forming discolored but not distorted areas, permanently embedded in the tissues; spores single, produced terminally or intercalary in the mycelium which does not entirely disappear through gelatinization, free (sometimes irregularly adhering through pressure), hyaline to yellowish or reddish-yellow, rarely dark-colored, germination by a short promycelium bearing a terminal group of sporidia which usually conjugate in pairs and produce secondary sporidia or infection-threads; sporidia often formed by germination of the spores *in situ*, the promycelium protruding through the stomata.

Twenty American species are recorded.

Foreign species are on Papaver, Ranunculus, Delphinium, Calendula, Thalictrum and several other hosts.

E. betiphilum Bub. is described on beet seed capsules;[30]

E. lephroideum for the same host in France;

E. calendulæ (Oud.) de B. on Calendula.

E. crastophilum Sacc.[5]

Sori in leaves, subcircular to linear, about 0.25–2 mm. in length, usually distinct though occasionally merged, black, long covered by the epidermis; spores dark-brown, tightly packed and adhering

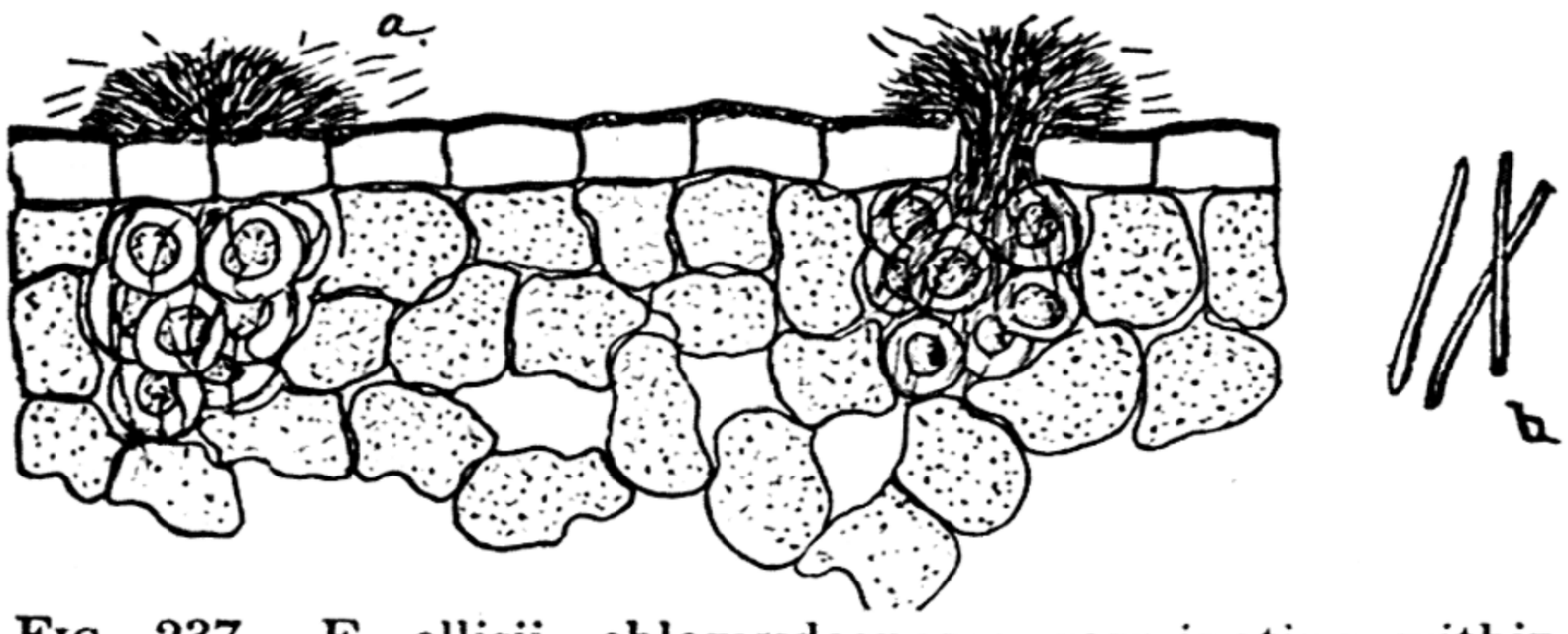


FIG. 237.—E. ellisii, chlamydospores germinating within the leaf tissue, sporidia superficial. After Halsted.

more or less, chiefly ovoid to spherical or angled through pressure, rather thick-walled, 8–14 μ in length.

On Poa, Phleum, Agrostis and other grasses in Europe and America.

E. irregulare Joh. occurs on species of Poa in Europe and America;

E. polysporum (Pk.) Farl. on various hosts including the common sunflower.

E. ellisii Hals.[31]

Sori in leaves, forming pale white spots, indefinitely limited, subconfluent; spores hyaline or slightly yellowish, clustered in the intercellular spaces beneath the stomata, spherical, thick-walled, (2–5 μ) chiefly 16–20 μ but varying from 11 to 25 μ in diameter; conidia hypophyllous, abundant, acicular, small, 10–14 μ by less than 1 μ.

On spinach, New Jersey.[31, 155]

The chlamydospores germinate *in situ* beneath the stomata and bear the sporidia on tufts of promycelia which emerge through the stomata, presenting much the appearance of a Hyphomycete.

E. australe Speg.

Sori foliar, forming spots, yellowish to eventually dark, usually 0.5–6 mm. in length; spores light to reddish-yellow, ovoid to spherical or slightly angled, chiefly 10–16 μ in length; conidia linear, somewhat curved, usually 30–55 x 1–2 μ.

Common and destructive on many species of Physalis and on Solanum, especially on some of the cultivated forms throughout the Americas and in Africa.

E. fuscum Schr.[156]

Sori in leaves, about 2–6 mm. or by confluence much larger, spores light yellow to chestnut-brown, provided (especially when young) with a conspicuously swollen gelatinous envelope, smooth, chiefly 13–19 μ in length; the hypophyllous matted outgrowths usually show few conidia which are fusiform, single-celled or septate, 10–22 x 3 μ.

It occurs on Papaver in Europe and Eastern North America.

E. nymphææ (Cunn.) Set.[157]

Sori in leaves, forming variable and irregular areas, usually most prominent on the under side, yellowish or with age reddish-brown, scattered or confluent; spores hyaline, ovoid to subspherical, usually apiculate and with the remains of the hypha as a basal appendix, smooth or under an immersion lens minutely verruculose, 10–14 μ in length; conidia not observed but spores said to germinate *in situ*.

On leaves of various water lilies in both the old and new world.

Doassansia Cornu.[147, 148] (p. 315)

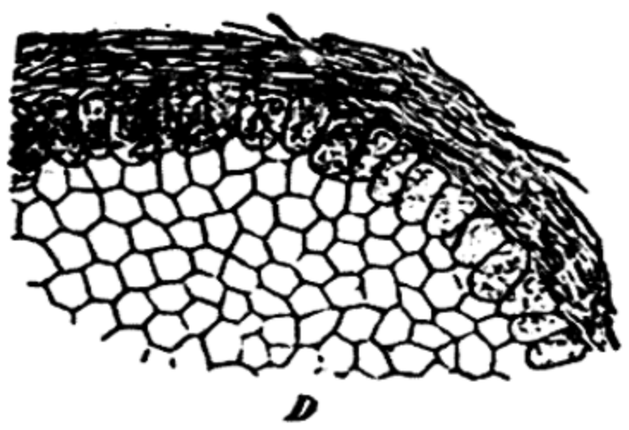


FIG. 238. — Doassansia. Part section through a spore ball showing sterile and fertile cells. After Dietel.

Sori in various parts of the host, usually in the leaves, rather permanently embedded in the tissues; spore-balls conspicuous, permanent, consisting of a distinct cortical layer and a central mass of fertile cells entirely filling the interior, or with the innermost cells supplanted by parenchymatous cells or hyphal threads; spores hyaline or yellowish, with smooth, usually thin, walls; germination often *in situ*, by means of a short promycelium which

gives rise to a terminal group of elongate sporidia, these often bearing secondary and even tertiary groups.

The only species of this genus which occur on economic plants are **D. gossypii** Lagerh.[32] on cotton in Ecuador and **D. niesslii** de Toni (Niess) Schr. on Butomus.

The following genera, which are usually referred doubtfully to the Ustilaginales will be found under "Genera of Unknown Affinity" page 663.

Graphiola Poit. on various palms. Schinzia Näg. on Solanum. Bornetina M. & V. on Vitis.

Protobasidii (p. 299)

The three orders which belong to this group are characterized by septate basidia.

Key to Orders of **Protobasidii**

Basidia with cross walls	
Basidia arising from chlamydospores,	
Life cycle polymorphic. Parasites.	1. **Uredinales,** p. 323.
Basidia not arising from chlamydospores	
Not polymorphic. Gelatinous saprophytes.	2. **Auriculariales,** p. 392.
Basidia with lengthwise partitions, gelatinous saprophytes.	3. **Tremellales.**

Uredinales [45, 49, 56, 60, 61, 166, 170–175, 178, 183–187 *]

Small fungi, mostly microscopic, parasitic in the tissues of ferns and seed plants. Mycelium much branched, septate, and with haustoria. Spores borne in sori below the surface of the host, or rarely single within the host. Sori naked, enclosed by peridia or paraphyses, or embedded in a thin stroma. Spores of five morphological sorts, not all present in every genus; (1) basidiospores, minute, thin-walled, without surface sculpturing, (2) pycniospores, small, smooth, of unknown function, (3) æciospores, verrucosely sculptured, borne in chains, (4) urediniospores, echinulately or

* Arthur's terminology involving the words pycnium, æcium, uredinium, telium and derivatives from these words, will be followed in the treatment of this order.

verrucosely sculptured, borne singly, or sometimes in chains, (5) teliospores, smooth or variously sculptured but not echinulate, borne singly or in chains. In every species the mycelium eventually gives rise to teliospores, which produce in germination four basidia, either remaining within the spore-cell or borne in the air on a short promycelium, each basidium supporting a single, stalked or sessile basidiospore.

The order of some two thousand species, constituting the "rust" fungi, many of them living on cultivated plants of high value, is of great economic significance. Its members are strict, obligate, parasites which in no stage of the life except in the promycelial stage can develop other than on the living host. The complexities of the life histories of the species, with their five distinct spore forms, inhabiting at different seasonal periods two or even three different host plants, renders the order both difficult and exceedingly interesting.

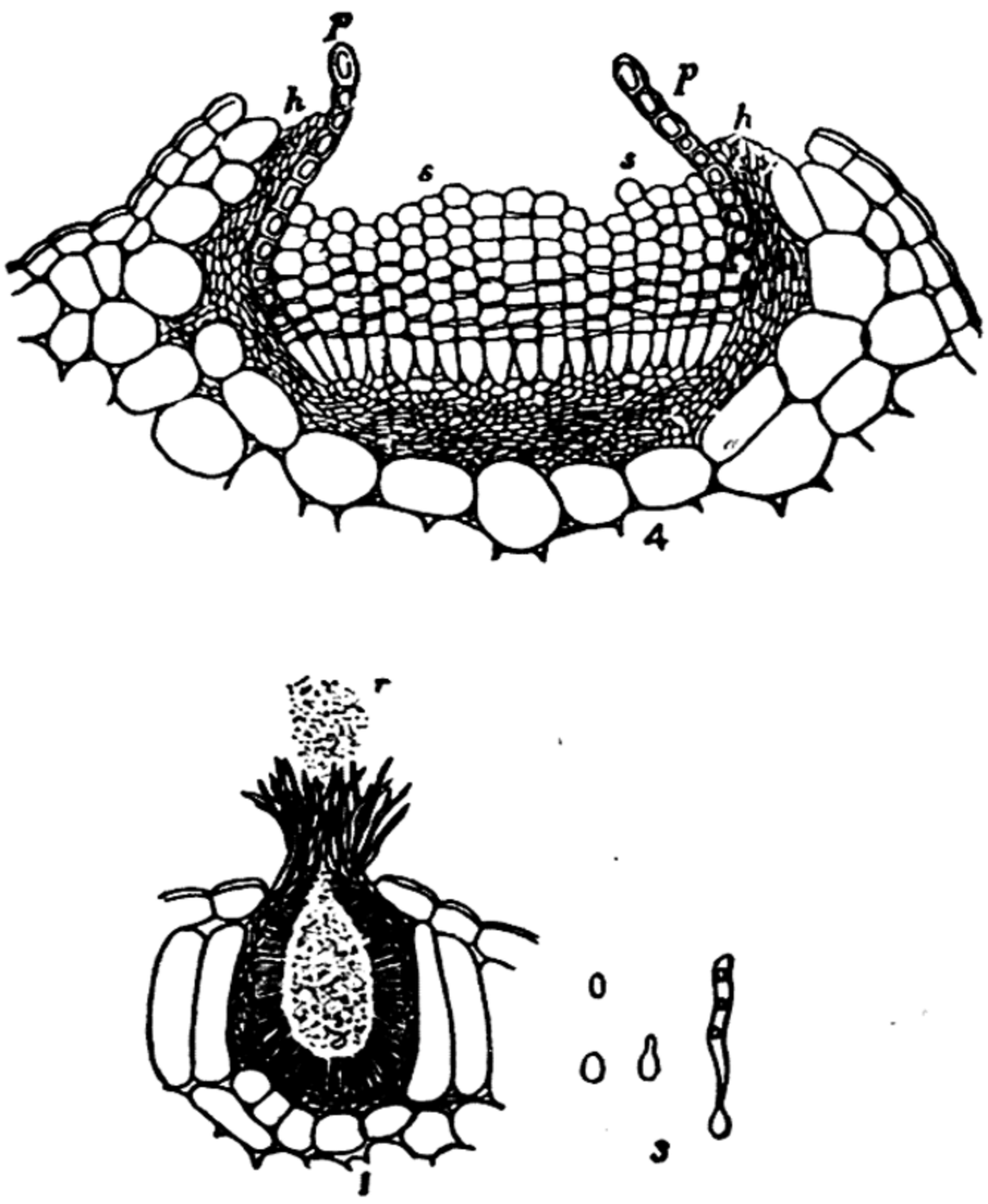


FIG. 239.—Æcium and pycnium. After Tavel.

The life history of the most complete of these fungi may be stated as follows:

I. **Æcia** (**æcidia**) and **O. pycnia** (often called spermogonia or pycnidia). The mycelium arising from a basidiospore invades the host plant, and vegetates until vigor sufficient to spore formation is attained, meantime often producing local spotting, hypertrophy, or other injury to the host. The mycelium then develops a stroma which produces spore beds (**sori**) and ruptures the epidermis. These sori are usually deeply sunken in the host and cup-shaped and take the common name "cluster cups," Fig. 239, technically **æcia** or **æcidia**. The sporophores arise from a hyphal plexus at the base of the cup and the spores are borne catenulate in acropetal suc-

cession. The whole structure is usually red or yellow. The outer layer of the cup usually consists of a palisade of sterile sporophores bearing sterile cells and constitutes the **peridium.** The **æciospores** are usually nearly globular, or angular by compression, reddish and rough and sometimes bear germ pores. They are capable of germination at once and on germination give rise to germ tubes which may infect susceptible hosts, leading to a mycelium. This in turn again produces sori which in some species may be æcia, in others telia, but in most species, uredinia.

Associated with the æcia, occasionally with other spore forms, but never borne alone, are minute **pycnia** with sporophores arising from their walls and bases. These bear unicellular pycniospores. Sterile hairs usually protrude from the ostioles. The whole structure in gross appearance is much like the pycnidium of Phoma or Phyllosticta but it is reddish or orange in color. These pycnia were formerly often spoken of as "spermogonia" and the spores as "spermatia," due to the thought that they stood for degenerated male organs; a view supported by the fact that the spores were not observed to germinate. Germination [258] has now been observed and there is no longer reason to regard them as sexual organs.

II. **Uredinia (uredo-sori).** The æciospores may infect the same species of plant that produced the æciospores (**autœcious**) or plants of an entirely different species (**heterœcious**). The mycelium produced by the æciospore develops within the host; usually remains local, and causes spotting. When it has attained sufficient vigor and age, usually after about two weeks, it produces a sub-epidermal hyphal plexus from which arises a bed of sporophores which bear unicellular, hyaline to brown, nearly globose, thin-walled, usually echinulate or rough spores, each with from 2 to 10 germ-pores variously placed. These are the **urediniospores** borne in **uredinia (uredo-sori).** They may germinate at once producing a germ tube which develops to a mycelium.

These spores falling on susceptible tissues, by infection, usually stomatal, continue the production of uredinia and spread the disease. The urediniospores are usually short-lived and function to spread summer infection. They continue to form throughout the growing season.

In a few species [187, 188] there are what are known as **amphispores** or resting forms of urediniospores provided with thickened walls. They have colorless contents and pedicels more persistent than those of the usual urediniospore.

III. **Telia (teleuto-sori).** Toward the latter part of the growing seasons another kind of spore appears, often in the same sorus with the urediniospore and from the same mycelium. It is of various forms in different genera, one or more-celled, varies in shape, thickness of wall, surface marking, color, etc., but is uniform in the character of the germination which is very different from that of any of the other rust-spores.

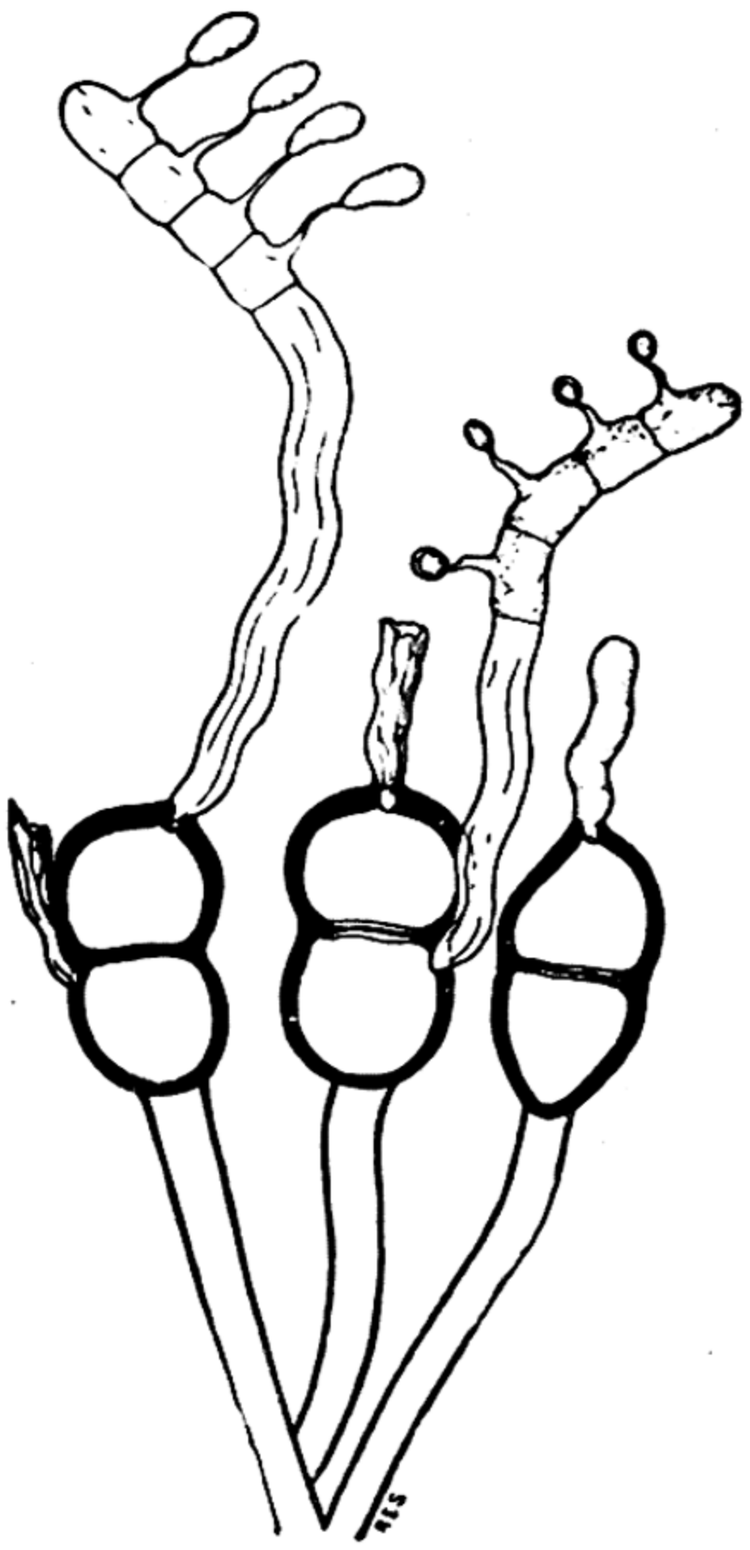


FIG. 240.—Germination of teliospores of P. asparagi. After Smith.

In **teliospore** germination, typically each cell of the teliospore sends forth one germ tube. These tubes soon cease growth and by septation become 4-celled. Each cell then sends out a short branch (sterigma) on which there develops one round or oval, 1-celled, thin-walled spore, the **basidiospore,** often in this group called the **sporidium.**

Morphologically the promycelium is a basidium bearing its four sterigmata and four basidiospores. Relationship is thus shown on the one hand to the Ustilaginales, on the other hand to the Auriculariales, an assumption that is borne out by cytological evidence. Deviations from the typical mode of germination are found in several genera mentioned below (e. g., Coleosporium).

Basidiospores germinate immediately by germ tubes which on suitable hosts give rise again to æcia and pycnia or in some species to other spore forms completing the life cycle.

The most complex life cycle is thus seen to comprise pycniospores, æciospores, urediniospores, teliospores and basidiospores. For brevity the first four stages are commonly designated by the following symbols:

O. Pycnia or pycnial stage
I. Æcia or æcial stage
II. Uredinia or uredinia stage
III. Telia or telial stage

The spores in all cases, except those of the basidiospores and

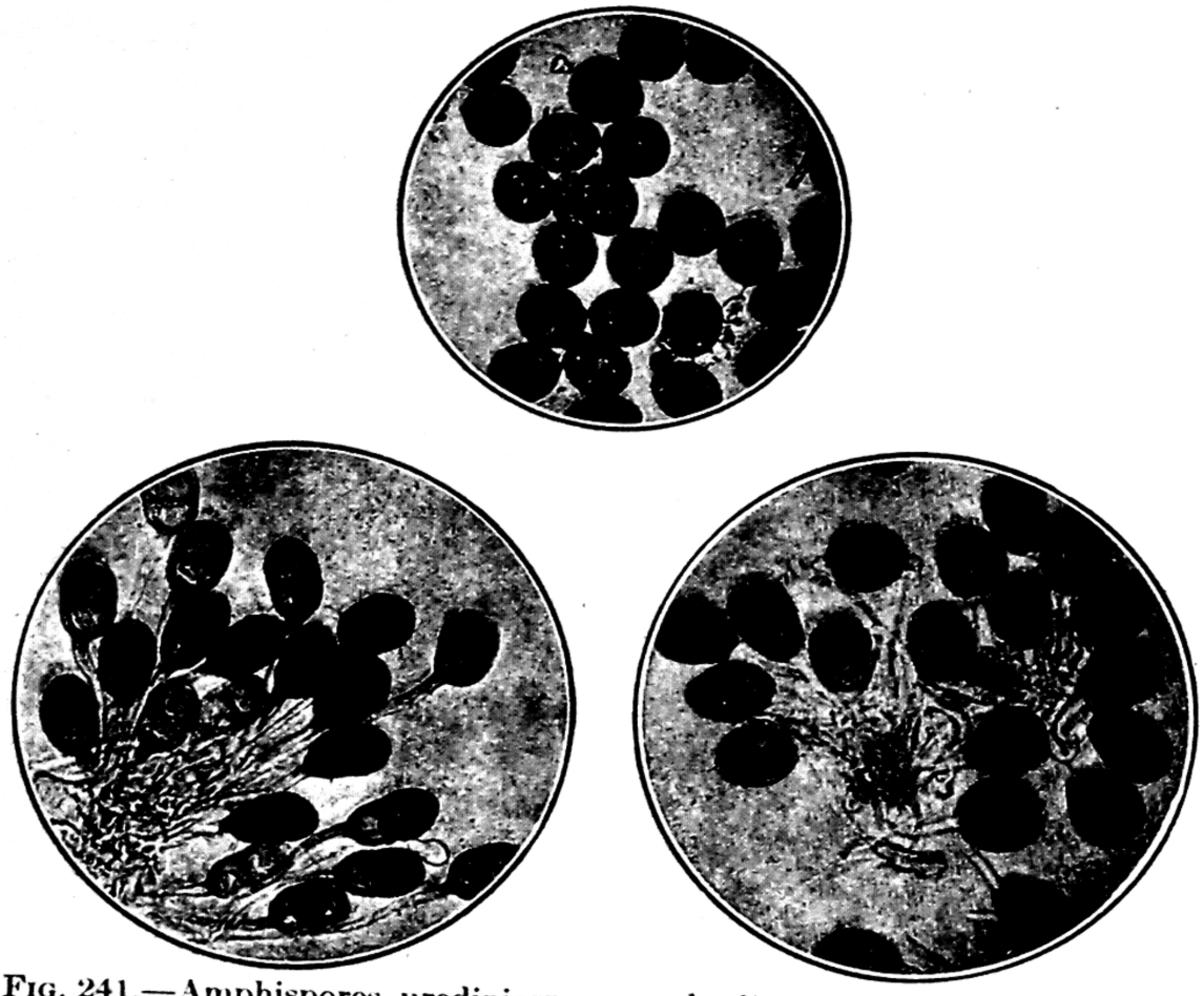


FIG. 241.—Amphispores, urediniospores and teliospores of Puccinia vexans. After Holway.

pycniospores arise by direct conversion of a mycelial cell into a spore, i. e., they are chlamydospores.

Mesospore is a term applied to occasional unicellular forms of teliospores found in Puccinia and related genera which do not usually have unicellular teliospores.

As has been said the pycniospores seem to be functionless though by some it is thought that they do function but that man has yet failed to find the conditions under which they readily germinate and cause infection. The æcial stage appearing first, and thus commonly in the spring, is often called the "spring stage."

It serves as an early stage to propagate and spread the fungus. The uredinia often called the "summer stage" constitute the phase usually of longest duration and of most injury. Its function is preëminently to multiply and spread the fungus.

The telia, often called the "winter stage," usually, but not always, constitute the resting, hibernating stage. In many instances the teliospores must rest over winter before they are capable of germination. Classification is based primarily on the teliospores.

While all five of the spore forms discussed above are typical of many species there are many other species which do not possess all of these forms or indeed which may possess only one spore form.

Schröter [7] for convenience groups the rusts, according to the spore forms that they show, under the following type names though it must be recognized that such grouping is purely artificial and does not necessarily bring together closely related species.

Eu-type	O,	I,	II,	III	present;
Brachy-type	O,		II,	III	present; I omitted.
Opsis-type	O,	I,		III	present; II omitted.
Hemi-type			II,	III	present; O, I omitted.
Micro-type			only	III	present; germination only after a resting period.
Lepto-type			only	III	present; germination without a resting period.

As examples of the above we have the following:

Eu-type, Puccinia asparagi, O, I, II, and III, all on Asparagus.

Brachy-type, Puccinia suaveolens, O, II, and III, all on thistle.

Opsis-type, Puccinia tragopogonis, O, I, and III, all on salsify.

Hemi-type, Uromyces caryophyllinus, II, and III, both on Dianthus.

Micro-type, Puccinia ribis, III, on Ribes.

Lepto-type, Puccinia malvacearum, III, on hollyhock.

Hundreds of the hemi-types will doubtless be revealed by study to be heterœcious eu-types.

Heterœcism.[320] All of the examples just given are **autœcious,** i. e., all known spore forms are found on the same species of host plant. In many other rusts, however, **heterœcism** prevails, i. e., one stage of the fungus is found on one species of host and another stage upon another host; rarely three host plants are involved in the cycle. Aside from the rusts only one other fungus (Sclerotinia ledi) is known to show heterœcism.

Heterœcism has been experimentally proved in some one hundred and fifty cases and may be assumed to exist in many hundreds of cases not yet investigated.

Examples of heterœcism are as follows:

	Stages O, I.	Stages II, III.
Eu-type, Puccinia graminis,	Berberis	Wheat
" rubigo-vera,	Boraginaceæ	"
" sorghi,	Oxalis	Corn
Uromyces pisi,	Euphorbia	Pea
Opsis-type, Gymnosporangium macropus,	Apple	Red cedar (III)

It frequently happens that part of the life cycle is passed upon a monocotyledonous plant, the remainder upon a dicotyledon. In such event it is more often the II and III stages that are on the monocotyledon while the O, I stages are on the dicotyledon; examples of this are afforded in the numerous rusts of grasses, sedges and rushes. In one group the pycnia and the

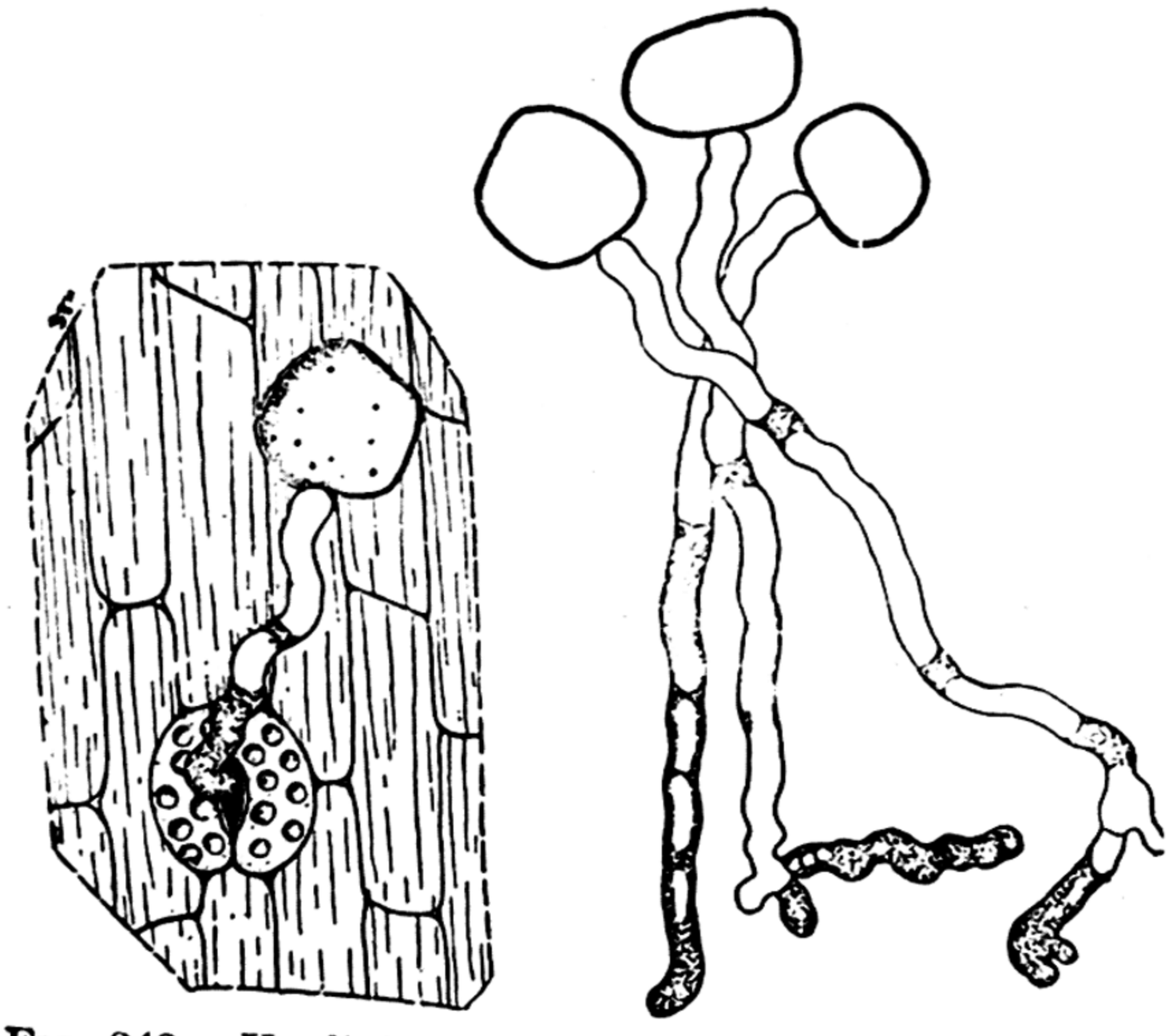


FIG. 242.—Urediniospore of P. asparagi germinating on surface of plant, and separate spores. After Smith.

æcia are on pines (Peridermium), while the other stages are on dicotyledons. In the Gymnosporangiums the pycnial and æcial stages are on Rosaceæ; the telial on Juniperus and its kin. While a few general rules can be worked out concerning host relations there are many exceptions and to know one stage of a heterœcious rust generally gives little or no clue to what its complementary host may be.

The mycelium of the rusts is usually intercellular and local though in a few instances it is extensive and even perennial in the host. It is abundantly branched, closely septate, gives off haustoria and usually bears numerous oil drops which lend a yellow or orange color.

Irritation by the mycelium often induces marked hypertrophy or even witches' brooms or other deformation of the host. Hypertrophy is most common with the æcia but may result from the telia as well, as is conspicuously shown in the genus Gymnosporangium. In some instances the whole habit of the host plant is altered by the presence of the mycelium so as to render it almost unrecognizable, e. g., the æcium of Uromyces pisi on Euphorbia.

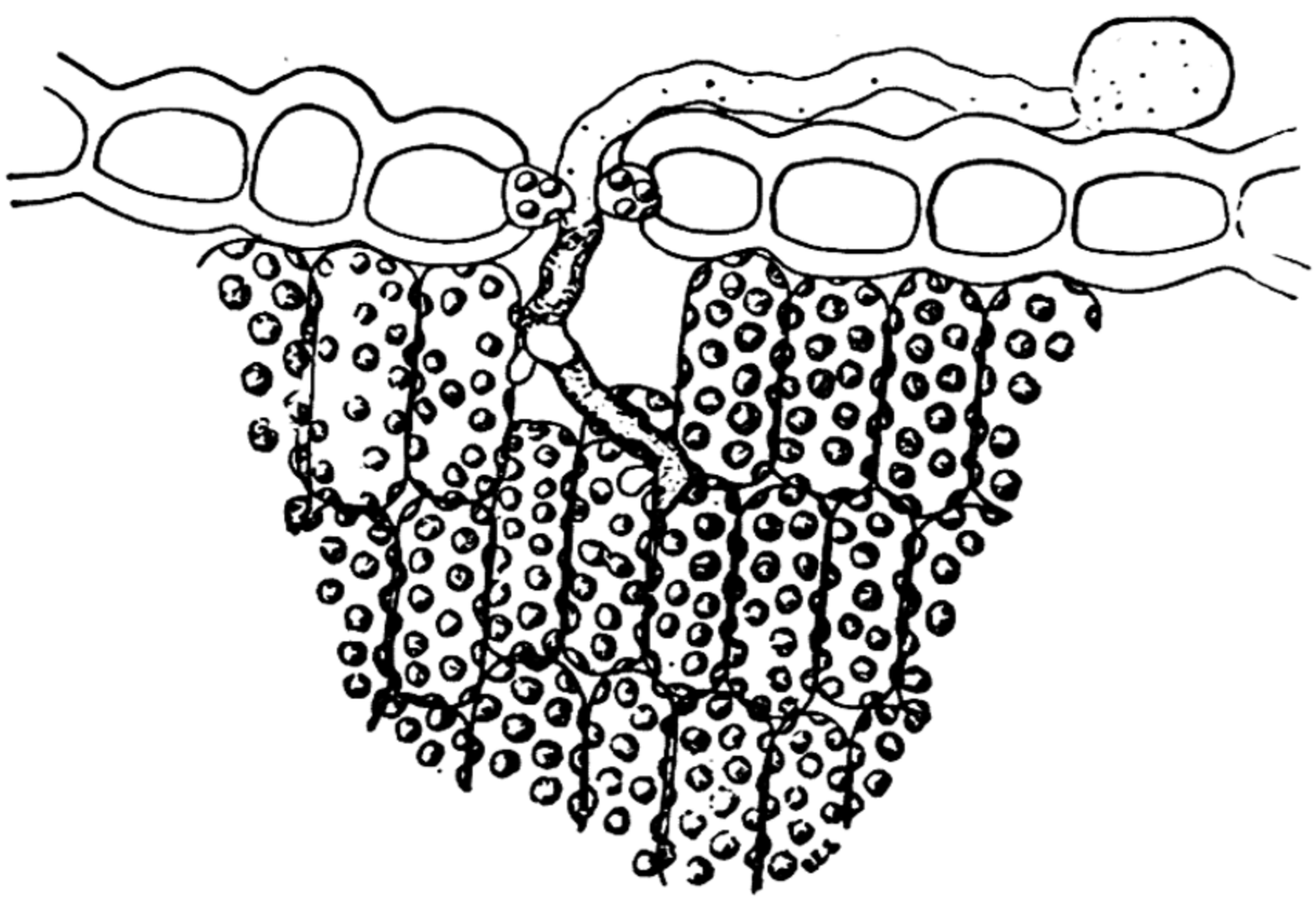


FIG. 243.—Cross-section, showing infection from spore of P. asparagi. After Smith.

The host cells are seldom killed by the mycelium, which abstracts its food supply from the carbohydrates and other nutrients of the cell sap without direct injury to the protoplasm, though ultimately there is serious effect upon both growth of the host and its seed production.

Cytology.[179, 180, 189, 313-315] Dangeard [314] and Sappin-Trouffy [313] showed that the mycelial cells of the rusts are binucleate, a condition which begins just below the æcium. The origin and significance of this condition is of much interest.

In all of the rusts so far investigated that have an æcium or primary uredinium there is in the æcio-mycelium or the primary uredinio-mycelium a fusion of uninucleated cells, gametes. This cellular fusion is not, however, followed by a nuclear fusion until after long delay; but the two nuclei remain in the fusion cell and when this cell divides both nuclei divide mitotically and simultaneously but still independently of each other (**conjugate division**). This process continues through the æcial sporophores, or uredinial sporophores, and in the production of the spores, with the result

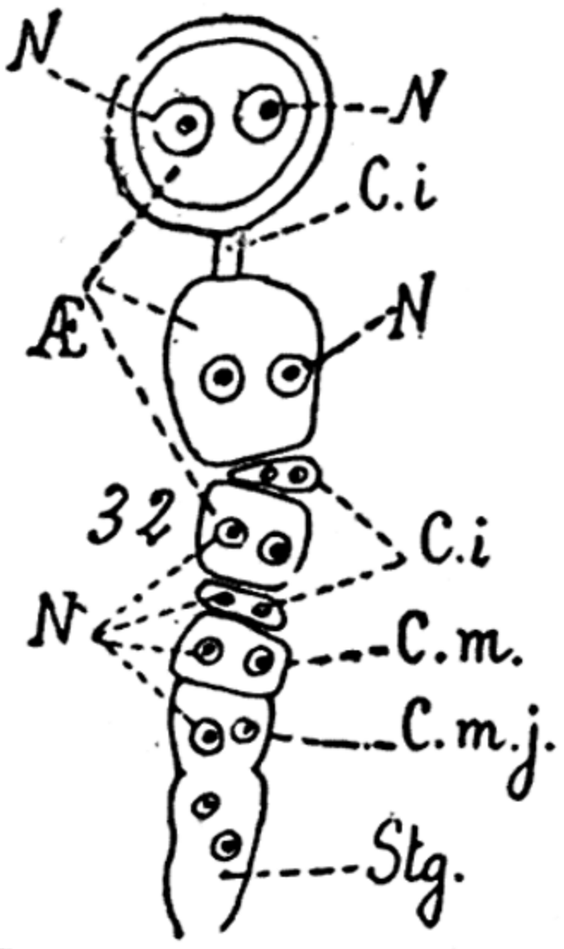


FIG. 244.—Showing conjugate nuclei and degenerating cells in conidiospore chain of Æcidium. After Sappin-Trouffy.



FIG. 245.—Gymnosporangium, clavariæforme, mitosis of a nucleus in the promycelium. After Blackman.

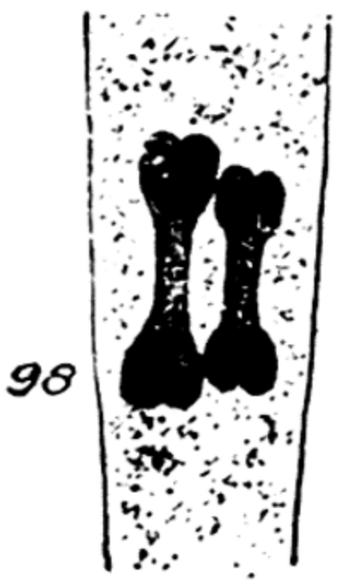


FIG. 246. — Conjugate nuclear division in Gymnosporangium clavariæforme showing four chromatin masses. After Blackman.

that the cells of all of these are binucleate. The conjugate division continues further through the uredinia and until teliospore formation occurs, the whole intervening series of cells being binucleate. Prior to the formation of the promycelium and in the teliospore the nuclei unite, reducing the cells again to an uninucleate condition.

In rusts which have only teliospores the binucleate condition begins somewhere in the mycelium from which the teliospores arise.

It is generally held that the cellular fusion is a sexual act with long delayed fusion of the sexual nuclei: and consequently that the uninucleate phase is the gametophyte; that the be-

ginning of the binucleate condition marks the origin of the sporophyte.

Biologic specialization [171, 172, 174, 309] much as is found in the Erysiphales occurs also in the Uredinales. There are many species, each of which is found on a large number of hosts. Upon its numerous hosts the fungus may show no morphological variation, yet at-

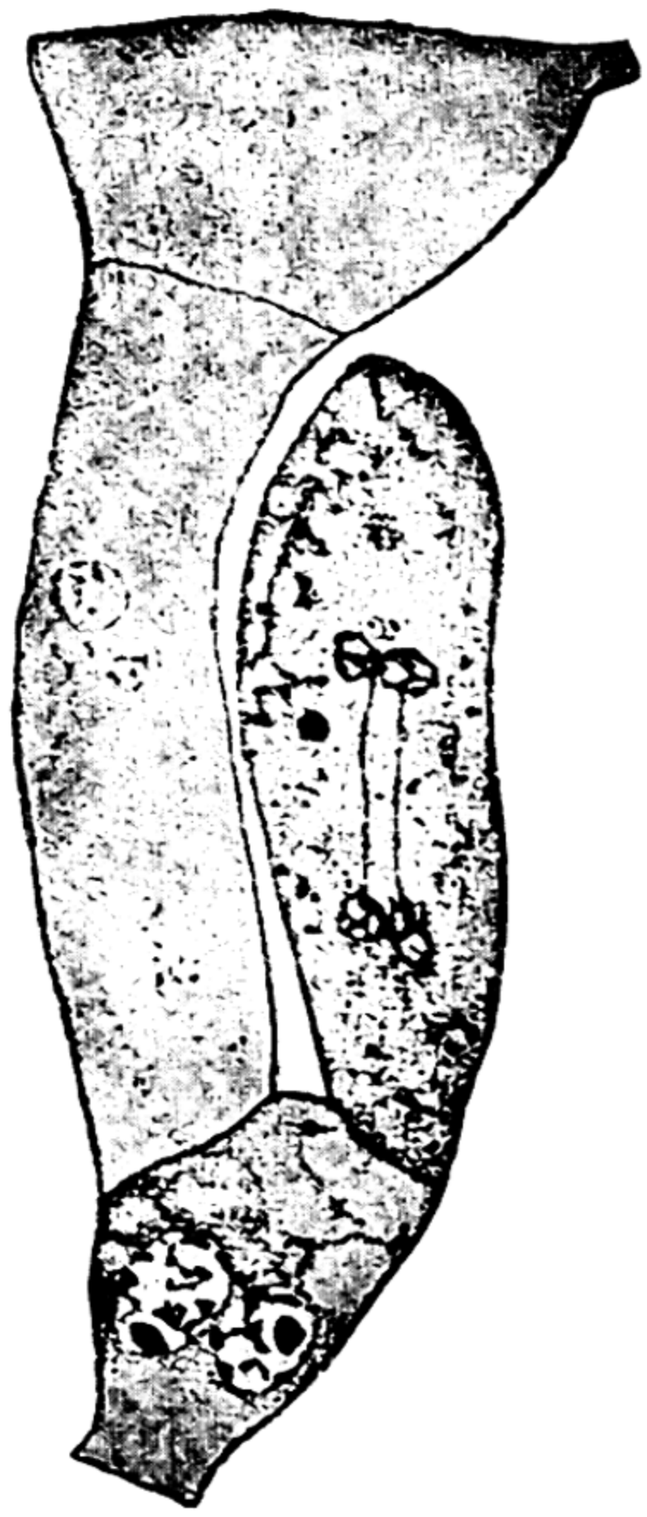


FIG. 247.—Conjugate nuclear division in cells of Puccinia podophylli. After Christman.

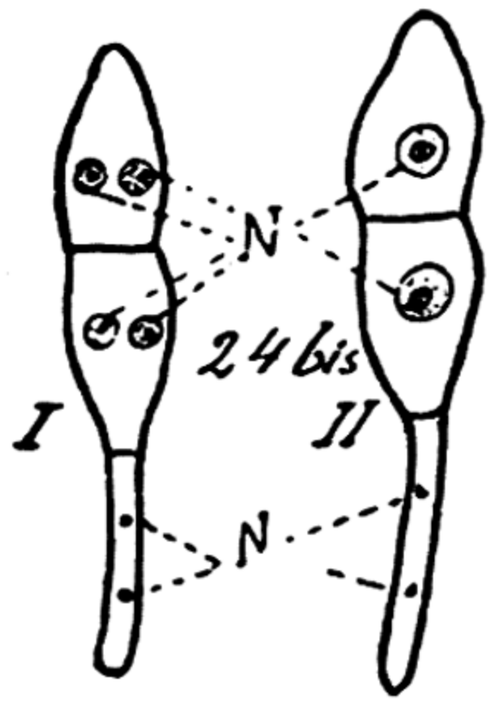


FIG. 248. — Diagrammatic representation of fusion of nuclei in the teliospore. After Delacroix and Maublanc.

tempts to inoculate from one host to another may uniformly give negative results. It further often occurs that one stage, e. g., the æcia of a species may grow upon only one host while the uredinia or telia may grow upon many different species of hosts; and in such cases that æciospores which have arisen on host X, from infection with spores from host A, are capable of infecting host A and that host only; while æciospores which have arisen on host X, by infection with spores from host B, are capable of infecting host B and only this host; and so on for numerous forms. Yet the uredinia and telia of these different races may be mor-

phologically inseparable as are also their æcia when grown upon their common host.

An excellent example of such biologic specialization is offered in the common pine Peridermium. Æcia may be produced upon the pine by sowing of Coleosporium teliospores from Senecio, Campanula, Pulsatilla, etc., but the æciospores which develop on the pine are capable of infecting only those species of hosts from which the teliospores were taken.

Similarly Eriksson [174] has determined that though rusts from many grains can infect the barberry, the æciospores there produced are not capable of infecting plants of species other than those from which the fungus was derived, or at most they can infect but a very limited number of species.

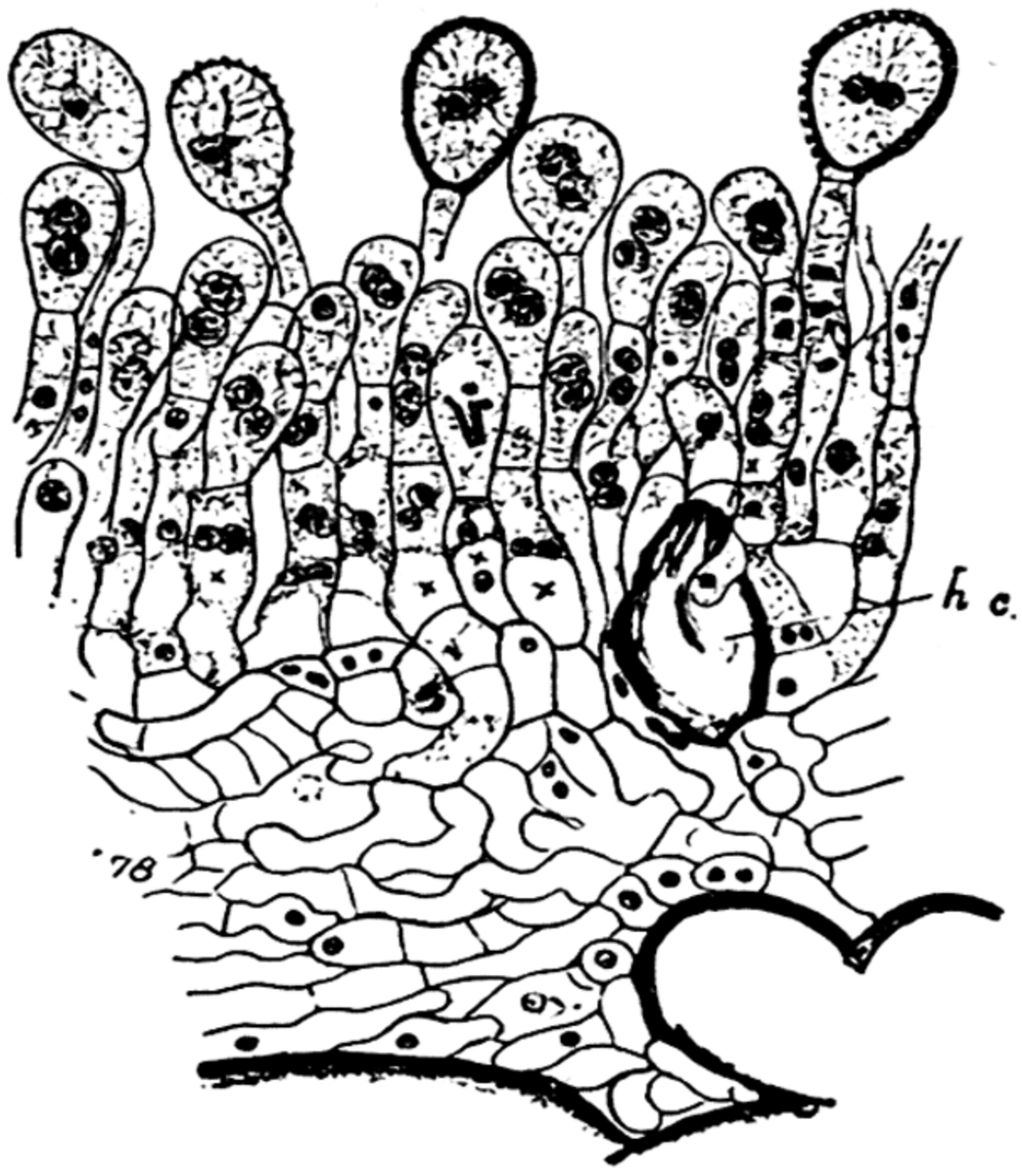


FIG. 249.—Urediniospores in Rubus showing nuclear conditions. After Blackman.

A further complication arises from the facts obtained through experiments in various countries, which have shown that what is apparently the same species may consist of a large number of strains or varieties which behave differently in different geographic areas. The stem rusts of wheat and barley, for instance, are very similar, interchanging hosts easily and being capable of transfer to various grasses in this country, though in Sweden the stem rust of wheat goes with difficulty to barley and rye, while the stem rusts of barley and rye interchange hosts very easily.

Owing to the prominence of its author and its place in literature a word may be given to the usually discredited **mycoplasm theory** [190-192, 312] of Eriksson. This affirms the existence in the cells of wheat grain of an intimate mixture of rust protoplasm and host protoplasm. This mycoplasm may rest thus for months. Finally the host-cell nucleus becomes digested and the fungous plasm develops to a mycelium which proceeds to invade the sur-

rounding tissues of the seedling as these develop on germination of the seed.

Infection Experiments. Since the method of studying the rusts by observing their life histories in the laboratory where they are under complete control of the observer has assumed such prominence of late years the technique deserves notice. The first step is to find associated in the field the æcia and other stages of a rust in such way as to suggest relationship between two forms hitherto unknown to be connected.

Material of the rust is then collected and healthy host plants are also removed to the laboratory. If the teliospores are collected in the fall they are kept out of doors in cheese cloth bags till germination time in the spring. Whether collected in spring or fall the viability of the spores must be tested by sowing in a hanging drop of water. If germination is plentiful then the infection experiment is made. First the suspected alternate host is sprayed with water to give the spores proper conditions for germination, then masses of spores are placed directly on the plant by a scalpel and a bell jar is placed over the plant to assure a humid atmosphere. In from five to eight days yellow spots should indicate where the infection has taken place and in a short time pycnia and æcia or other sori follow. In all infection work it is imperative to know that the plants used be not already infected in the field from another source.

The æcium is by some regarded as a structure whose function is to restore vigor to the rust fungus.[308] On the other hand, Freeman and Johnson [306] found that in fifty-two generations of the fungus, without the intervention of æcia or telia there was no apparent diminution in the vitality of the uredinial generation.

Form Genera. The telial stage is regarded as the highest stage of the rust fungus and is the one on which classification is often based. Thus an æcium, uredinium, cæoma, etc., that is known to possess a telial form is regarded as part of the species indicated by its teliospore, e. g., Æcidium berberidis being part of Puccinia graminis has no specific identity but is regarded as a stage of P. graminis.

There are numerous uredinia, æcia and other non-telial forms

of which the telial stage is not yet known. It becomes necessary for the present, for convenience of reference, to have names by which to designate these forms. For this purpose the form-genera Æcidium Cæoma, Peridermium, Rœstelia and Uredo are recognized. We group these under the heading **Uredinales Imperfecti.**

Darluca and Tuberculina, two imperfect fungi, are often found growing as parasites upon the rust fungi.

Key to Families of Uredinales

Teliospores in germination becoming 4-celled, compacted laterally into waxy layers; walls of the spores weakly gelatinous.....	1. **Coleosporiaceæ, p. 335.**
Teliospores germinating by a promycelium	
Teliospores compacted laterally into a crust or column (rarely solitary within the tissues); walls of the spores firm	2. **Melampsoraceæ, p. 340.**
Teliospores free or fascicled; walls of the spores firm or with an outer hygroscopic layer covered by cuticle.....	3. **Pucciniaceæ,** p. 353.
Teliospores unknown.....	4. **Uredinales Imperfecti,** p. 389.

Coleosporiaceæ

Teliospores united in a one or two-layered waxy cushion, sessile or borne on a broad sac-like stalk and then at the beginning 2-celled. Each original spore-cell divides to four super-imposed cells from each of which a simple sterigma emerges. This bears a large basidiospore.

The most important character is the peculiar mode of basidiospore production, the 4-celled promycelium being formed within the spore.

The family is of little economic importance except in its æcial stage on conifers.

KEY TO GENERA OF **Coleosporiaceæ.**

Basidiospore spindle-shaped. . . . . 1. **Ochropsora, p. 336.**
Basidiospore ellipsoid
  Teliospores in a single layer
    Teliospore layer strongly arched, forming minute knobs . . . . . 2. **Mikronegeria.**
    Teliospore in a flat crust. . . . . 3. **Coleosporium,** p. 336.
  Teliospores in a double layer, long-stalked . . . . . 4. **Chrysopsora.**
  Teliospores in a columnar mass . . . . . 5. **Trichopsora.**

Ochropsora Dietel

II. Urediniospores solitary.

III. Teliospores in a waxy crust, loosely united, originally 1-celled, later 4-celled, each cell bearing a single basidiospore on a simple sterigma.

O. sorbi (Oud.) Diet.

I. Æciospores (=Æ. leucospermum) on anemone.

II and III. Urediniospores on Sorbus and Spirea.

Coleosporium Léviellé

O. Pycnia flattish, linear, dehiscent by a slit, without ostiolar filaments.

I (=Peridermium). Æcia erumpent, definite. Peridium colorless with verrucose walls. Spores globose to oblong, with colorless walls, the outer part formed of densely packed, deciduous tubercles.

II. Uredinia erumpent, definite, without peridium. Spores catenulate, globoid to oblong, pulverulent; wall colorless, closely verrucose, pores obscure.

III. Telia indehiscent except through weathering, waxy, somewhat indefinite, usually roundish. Spores sessile, 1-celled (by early division of the contents appearing 4-celled); wall smooth, colorless, thickened and gelatinous at apex.

The genus is usually heteræcious. Arthur [49] lists some twenty-four species for America.

There are many biologic forms, morphologically indistinguish-

able yet not inter-inoculable. The æcial stage is found on leaves of conifers, the telia on a large variety of hosts.

C. ipomœæ (Schw.) Burr.

O and I. Unknown.

II. Uredinia hypophyllous, widely scattered or somewhat clustered, 0.25–1 mm. across, early naked, orange-yellow fading to white, ruptured epidermis usually inconspicuous; spores ellipsoid, 13–21 x 18–27 μ, more or less angular and irregular; wall thin, 1–1.5 μ, closely and noticeably verrucose.

III. Telia hypophyllous, widely scattered, often confluent, pulvinate, 0.5 mm. or less across, deep reddish-orange fading to pale-yellow; spores with wall swelling 20–40 μ above; contents orange-yellow fading to colorless, oblong, or slightly clavate, 19–23 x 60–80 μ, rounded or obtuse at both ends.

Common on various Iponœas and their kin among them morning glory and sweet potato.[194]

C. solidaginis (Schw.) Thüm.[49, 195-197]

O. Pycnia amphigenous, scattered, numerous, originating between mesophyll and cortical layer, noticeable, 0.3–0.5 mm. wide by 0.5–0.8 mm. long, dehiscent by a longitudinal slit, low-conoidal, 80–100 μ high.

I (=Peridermium acicolum). Æcia from a limited mycelium, amphigenous, numerous, scattered on discolored spots occupying part of a leaf, erumpent from longitudinal slits, tongue-shaped, 0.5–1 mm. long by 0.5–0.7 mm. high; peridium rupturing irregularly, moderately firm, white, cells overlapping, 35–45 μ long, not much narrower, walls transversely striate, inner coarsely verrucose, thick, 5–6 μ, outer less rough and somewhat thinner; spores ellipsoid, 20–25 x 28–40 μ; wall colorless, closely and coarsely verrucose with deciduous tubercles which are directed away from a smooth spot extending up one side, thick, 2–3 μ on the smooth spot, increasing to 5–6 μ on the opposite side, including the tubercles.

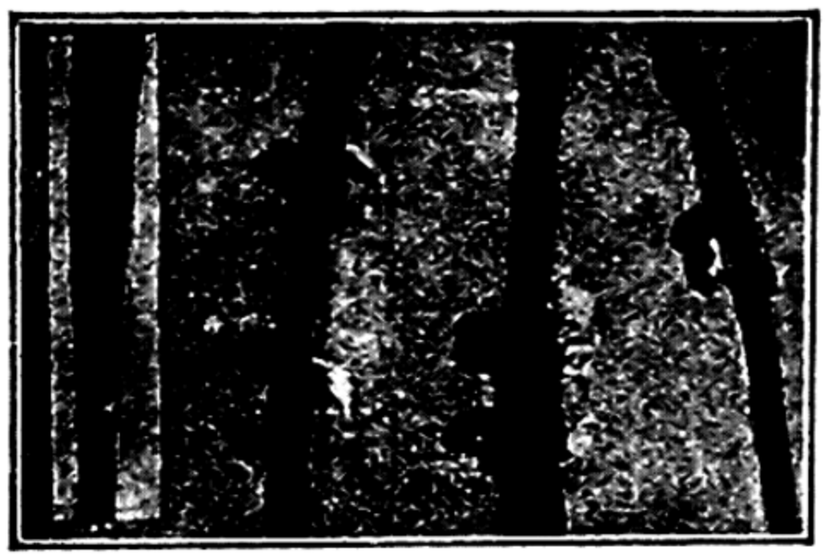


FIG. 250.—Stages O. and I. of Coleosporium solidaginis (Peridermium) on Pinus rigida. After Clinton.

II. Uredinia hypophyllous, rarely also epiphyllous, irregularly

scattered, or at first somewhat gregarious and crowded, 0.3–0.5 mm. across, soon naked, yellow or orange-yellow, ruptured epidermis inconspicuous; spores ellipsoid or globoid, 17–22 by 20–30 μ; wall rather thin, 1–2 μ, closely and strongly verrucose; contents orange-yellow when fresh, fading to colorless.

III. Telia hypophyllous, scattered irregularly or sometimes crowded and confluent, slightly elevated, 0.3–0.5 mm. across, reddish-orange; spores with wall swelling 30–40 μ thick above; contents orange-yellow fading to colorless, terete, 15–23 x 55–80 μ, rounded or obtuse at both ends; basidiospores globoid or elliptical, about 12 x 18 μ, orange-yellow.

I. Æcia on Pinus rigida.

II and III. Uredinia and telia on Aster, Solidago and cultivated aster (Callistephenis); widespread and common. The connection between the stages was demonstrated by inoculations by Clinton.[196, 197]

C. senecionis (Schum.) Fries.

O. Pycnia amphigenous, scattered, numerous, originating between mesophyll and cortical layer, noticeable, 0.2–0.3 mm. wide, 0.5–1 mm. long, dehiscent by a longitudinal slit, 70–100 μ high.

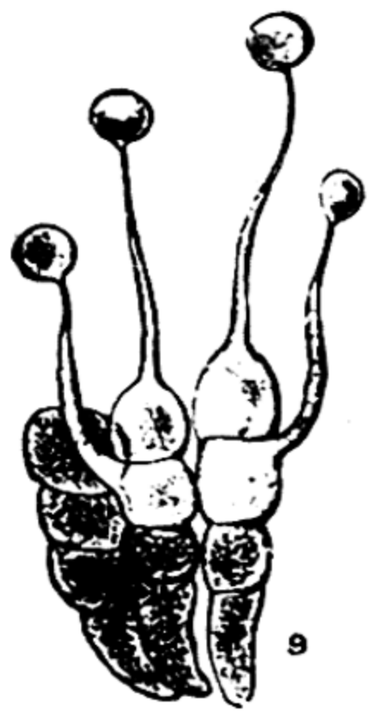


FIG. 251. — Coleosporium senecionis, showing germination of teliospores. After Plowright.

I (=Peridermium oblongisporium). Æcia from a limited mycelium, amphigenous, bullate, tongue-shaped, 1–2 mm. long, 0.7–1 mm. high, whitish; peridium rupturing irregularly, fragile, white, cells overlapping outer and inner walls of same thickness, 3–4 μ, outer smooth, inner moderately verrucose; spores broadly ellipsoid, 17–24 by 28–36 μ, wall colorless, thick, 3–4 μ, densely verrucose with prominent elongate papillæ.

II. Uredinia hypophyllous, thickly scattered, about 0.5 mm. across; early naked, bright orange-yellow fading to pale-yellow, ruptured epidermis evident; spores elliptical-globoid or obovate-globoid, 17–21 by 20–27 μ; wall thin, 1–1.5 μ, evenly but not densely verrucose, with low papillæ.

III. Telia hypophyllous, scattered, often confluent, small, 0.3 mm. across, brilliant orange-yellow fading to pale orange-yellow;

spores with wall swelling 15–25 μ thick above; contents orange-yellow fading to pale-yellow, clavate or clavate-oblong, 16–20 by 60–83 μ, rounded at both ends or narrowed below.

I. Æcia on Pinus sylvestris.

II and III. Uredinia and telia on Senecio. What may be this same fungus is reported also on cultivated Cineraria.[198] The teliospores hibernate in their dark-red sori producing promycelia in the spring. The sporidia bring about spring infection of the pine leaves and young twigs, later resulting in pycnia and æcia. The connection of the forms was established by Wolff in 1872.

C. pini Gall.[49, 199]

O. Pycnia unknown, probably wanting.

III. Telia amphigenous, on yellow spots, usually near the tips of the leaves, long covered by the epidermis, 1–5 mm. long, or when confluent up to 10 mm. or more, reddish-orange fading to pale-yellow or dirty-white, ruptured epidermis inconspicuous; teliospores with walls swelling 30–50 μ above, and soon disappearing upon exposure; contents orange-yellow fading to nearly colorless, clavate, slender, 13–20 by 60–100 μ, acute or rounded above, much narrowed below, sides wavy or irregular.

This is set apart by Arthur[49] as the type of a distinct genus, Gallowaya, based on the absence of spore forms other than the teliospores.

It causes serious leaf loss on Pinus virginiana.

C. campanulæ (Pers.) Lév.[200]

O. Pycnia amphigenous, scattered, numerous, originating between mesophyll and cortical layer, noticeable, large, 0.2–0.4 mm. wide, 1–2 mm. long, dehiscent by a longitudinal slit, 90–110 μ high.

I (=Peridermium rostrupi). Æcia from a limited mycelium, amphigenous, scattered, 1–3 on discolored spots, bullate, tongue-shaped, large, 1–3 mm. long, 0.7–1.5 mm. high, yellow, fading to white; peridium rupturing irregularly, fragile, white, cells overlapping, outer and inner walls same thickness, about 4–6 μ, outer smooth, inner moderately verrucose; spores broadly ellipsoid or globoid, 17–22 by 22–31 μ; wall colorless, thin, 2–3.5 μ, densely verrucose, with prominent, elongate papillæ.

II. Uredinia hypophyllous, scattered, often confluent, 0.5–1 mm.

across, soon naked, orange-red fading to white, ruptured epidermis evident; spores ellipsoid, 18–23 by 20–30 μ; wall thin, 1–1.5 μ, densely verrucose, with prominent, elongate papillæ.

III. Telia hypophyllous, scattered, often confluent, small, 0.2–0.5 mm. across, slightly elevated, blood-red, fading to pale brownish-yellow; spores with wall swelling 15–25 μ thick above; contents orange-red fading to nearly colorless, cylindrical or clavate-oblong, 17–24 by 55–85 μ, rounded or obtuse at each end.

O and I on Pinus rigida.

II and III on Campanula and kin.

There are numerous other species of less importance.

Melampsoraceæ (p. 335)

Telia forming a more or less definite crust or column; teliospores compacted laterally into layers or rarely solitary in the tissues, sessile; wall firm or rarely with a gelatinous layer.

The family is of little importance. Its uredinial and telial stages do slight injury on poplars and willows.

Key to Genera of Melampsoraceæ.

Telia indehiscent.	
Sori all subcuticular; teliospores compacted in dense layers to form a crust; æcia when present without a peridium; uredinia when present without a peridium or with an imperfect one of paraphyses	
Teliospores in a single layer; uredinia with spores and paraphyses intermixed	1. **Melampsora**, p. 342.
Teliospores in more than one layer	
Uredinia with peripheral paraphyses only	2. **Physopella**, p. 345.
Uredinia without paraphyses	3. **Bubakia.**
Pycnia subcuticular, other sori subepidermal, or the telia within the epidermal cells or between the mesophyll cells; uredinia when present with a peridium	

Teliospores approximating in a single layer within or beneath the epidermis; urediniospores globoid to oblong
Walls of the teliospores colored
Urediniospores echinulate throughout. . . . . 4. **Pucciniastrum,** p. 346.
Urediniospores echinulate except at the apex. . . . . 5. **Melampsoridium,** p. 347.
Walls of the teliospores colorless
Urediniospores echinulate. . . . . 6. **Melampsorella,** p. 348.
Urediniospores verrucose. . . . . 7. **Hyalopsora.**
Teliospores solitary within the mesophyll; urediniospores pointed . . . . 8. **Uredinopsis.**
Telia erumpent, sori all subepidermal
Teliospores compacted laterally; æcia when present with flattened peridium, rupturing apically; uredinia when present with a delicate peridium and catenulate spores
With all spore forms in life cycle. . . . . 9. **Melampsoropsis,** p. 349.
With telia and pycnia only
Promycelium of the ordinary type. 10. **Chrysomyxa,** p. 350.
Promycelial cells changing directly to basidiospores. . . . . 11. **Barclayella.**
Teliospores often adhering and extruded in long columns; æcia when present with inflated peridium, dehiscence circumscissile; uredinia when present, with peridium, spores borne singly on pedicels.
Teliospores 1-celled
Telia naked
Telia forming columns
Teliospores firmly united sidewise and endwise. . . . . 12. **Cronartium,** p. 350.
Teliospores loosely united laterally, separating in disks. . . . 13. **Alveolaria.**
Telia not extruded
Wall brownish, thick . . . . . 14. **Bæodromus.**
Wall colorless, thin. . . . . 15. **Cerotelium.**

Wall slightly colored. . . . . 16. **Cionothrix.**
Telia with a peridium
Telia half projecting above the host surface. . . . . 17. **Lietelia.**
Telia sunken in the tissue of the host. . . . . 18. **Endophyllum, p. 353.**
Teliospores 2-celled
Peridium present. . . . . 19. **Pucciniosita.**
Peridium none. . . . . 20. **Didymopsora.**

Melampsora Castaigne (p. 340)

O. Pycnia half spherical.
I. Æcia of cæoma-type, no peridium or paraphyses.
II. Urediniospores solitary, membrane colorless.

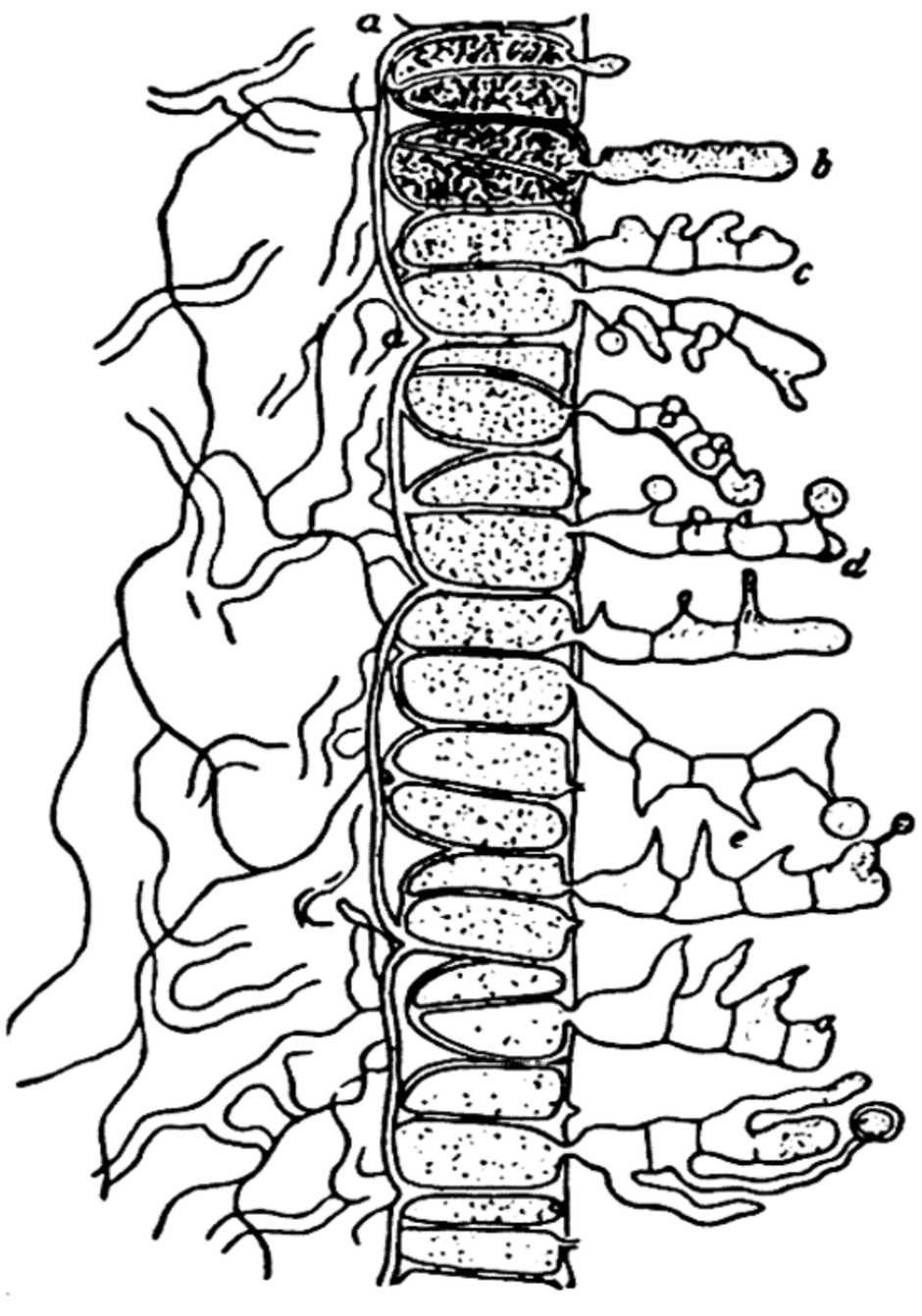


FIG. 252.—Pucciniastrum goeppertianum, showing germinating teliospores. After Hartig.

III. Teliospores 1-celled, rarely more, in flat irregularly limited crusts. Basidiospores spherical.

The question of biologic specialization is especially complicated in this genus. The uredinial and telial stages occur in abundance on willows and poplars, the æcial stage on a wide range of plants embracing gymnosperms, monocotyledons and dicotyledons.

M. lini D. C.

O. Pycnia amphigenous, numerous, scattered, inconspicuous, subepidermal, pale-yellow, flattened globoid or lens-shaped, 100–175 μ in diameter, 65–95 μ high; spores ellipsoid, 2–3 by 3–4 μ.

I. Æcia chiefly hypophyllous, numerous, scattered, rounded, 0.2–0.4 mm. across, bright orange-yellow, conspicuous, formed between epidermis and mesophyll, soon naked, ruptured epidermis evident; spores globoid, 19–27 x 21–28 μ.; wall colorless, thin, about 1 μ, finely and evenly verrucose, with distinct papillæ, pores not evident.

II. Uredinia amphigenous and caulicolous, scattered or somewhat gregarious, often crowded, round or on stems elongate, 0.3–0.5 mm. across, soon naked, reddish-yellow fading to nearly white, pulverulent, ruptured epidermis noticeable; spores broadly elliptical or obovate, 13–18 x 15–25 μ, wall colorless, rather thin, 2 μ, evenly and finely verrucose, with low papillæ, pores equatorial, obscure; paraphyses intermixed with the spores, capitate, large, 5–22 x 40–65 μ, smooth, wall thick.

III. Telia amphigenous and caulicolous, scattered, often confluent, round or elongate, 0.2–0.5 mm. across, slightly elevated, reddish-brown becoming blackish; spores subepidermal, appressed into a single layer, prismatic, 1-celled, 10–20 x 42–50 μ; wall brown, smooth, thin, about 1 μ, not thickened above.

Autœcious on flax. Sometimes very injurious.[203]

M. medusæ Thüm.

O. Pycnia chiefly epiphyllous, scattered or somewhat gregarious, minute, punctiform, pale-yellow, inconspicuous, subcuticular, hemispherical, 40–80 μ in diameter, half as high.

I. Æcia chiefly hypophyllous, scattered or somewhat gregarious, small, 0.1–0.3 mm. broad, round or oblong, pale-yellow fading to white, inconspicuous, formed between epidermis and mesophyll, soon naked, pulverulent, ruptured epidermis noticeable; æciospores globoid, 17–22 by 17–24 μ; wall colorless, thick, 2.5–3 μ, minutely verrucose, with minute crowded papillæ, pores indistinct.

II. Uredinia amphigenous, or only hypophyllous, scattered, roundish, small, 0.2–0.4 mm. across, early naked, somewhat pulverulent, orange-yellow, fading to pale brownish-yellow, ruptured epidermis usually inconspicuous; urediniospores ellipsoid or obovate-ellipsoid, 15–18 by 22–30 μ, usually flattened laterally; wall colorless, 2.5–3 μ or up to 10 μ on the flattened sides, sparsely and evenly verrucose, with fine papillæ, except on the flattened sides which are smooth; paraphyses numerous, intermixed with the spores, capitate, smooth, 40–65 μ long, head 14–25 μ broad, wall thick, 3–6 μ, peripheral paraphyses thinner-walled and more clavate.

III. Telia amphigenous or only hypophyllous, scattered or somewhat confluent, irregularly roundish, small, 0.2–0.4 mm.

across, slightly elevated, light reddish-brown, becoming deep chocolate-brown, subepidermal; teliospores prismatic, 12–15 by 30–45 μ; wall smooth, cinnamon-brown, uniformly thin, 1 μ.

O and I on Larix, II and III on Populus. Common on all species of Populus and often doing serious damage by its early defoliation of the trees.

M. bigelowii Thüm. with O and I on Larix and II and III on Salix is quite similar to the preceding. It occurs on practically all species of willow.

Other species not found in America are:

M. allii-fragilis Kleb.[311]

I on Allium vineale and A. sativum.

II and III on Salix.

M. allii-salicis albæ Kleb.[311]

I on Allium.

II and III on Willow.

M. allii-populina Kleb.[311]

I on Allium.

II and III on Populus.

M. klebahni Bub.

I on Corydalis.

II and III on Populus.

M. larici-pentandræ Kleb.[311]

I on Larix.

II and III on Salix.

M. larici populina Kleb.[311]

I on Larix.

II and III on Populus.

M. pinitorqua Rost.[311]

I (=Cæoma pinitorquum). The Cæoma-stage is quite destructive to pine seedlings. The teliospores grow on Populus leaves.

M. repentis Plow.

I (=Cæoma orchidis); on Orchis. II and IIIon Salix.

M. ribesii-viminalis Kleb.[311]

I on Ribes. II and III on Salix.

M. rostrupii Wagn.[311]

I on Mercurialis. II and III on Populus.

M. saxifragarum (D. C.) Schr.
I and III on Saxifrages.

Physopella Arthur (p. 340)

Cycle of development imperfectly known; only uredinia and telia recognized, both subepidermal. Uredinia erumpent, definite, roundish, pulverulent, encircled by more or less clavate paraphyses which are often united at their bases, or wholly, into a pseudoperidium opening by a central pore. Urediniospores borne singly on pedicels, obovate-globoid or ellipsoid; wall pale-yellow, echinulate or rarely verrucose, pores obscure. Telia indehiscent, forming lenticular masses, two or more cells thick at center. Teliospores 1-celled; walls smooth.

P. vitis (Thüm.) Arth.[49]

II. Uredinia hypophyllous, scattered thickly over wide areas, round, minute, 0.1 mm. or less across, soon naked, arising between epidermis and mesophyll, surrounded by numerous incurved paraphyses, pulverulent, pale-yellow, fading to dirty white, ruptured epidermis inconspicuous; urediniospores broadly ellipsoid or obovate, 13–17 by 18–27 μ; wall nearly colorless, thin, 1 μ, minutely and rather closely echinulate, pores obscure; paraphyses hyphoid, curved and irregular, 6–10 μ thick, 30–60 μ long, wall uniformly thin, 1 μ, yellowish.

III. Telia hypophyllous, scattered thickly over large areas, roundish, minute, 0.1–0.2 mm. across, indehiscent, 3 to 4-cells thick; teliospores ovoid, 12–15 by 20–30 μ, wall smooth, nearly colorless, thin, 1 μ or less.

On grape leaves in Southern United States and West Indies. Also in South America and Japan.

P. fici (Cast.) Arth.[49]

II. Uredinia hypophyllous, scattered thickly over large areas, roundish, usually small, 0.1–0.3 mm. across, or rarely larger, bullate, arising between epidermis and mesophyll, tardily dehiscent by central rupture, encircled by delicate, evanescent paraphyses, pulverulent, pale cinnamon-brown, ruptured epidermis overarching or erect; spores obovate-globoid, 14–20 by 18–27 μ; wall pale-yellow, thin, 1–1.5 μ, sharply and rather sparsely echinulate, pores ob-

scure; paraphyses hyphoid, very delicate, collapsing, 60–80 μ long, wall colorless, very thin, slightly thickened at apex, 1 μ.

III. Telia, unknown.

II. On fig and osage orange.

Pucciniastrum Otth. (p. 341)

Heterœcious. The cycle of development includes pycnia, æcia, uredinia and telia, with distinct alternating phases.

O. Pycnìa subcuticular, low-conoidal, without ostiolar filaments.

I. Æcia erumpent, cylindrical. Peridium delicate, verrucose on inner surface. Spores ellipsoid, verrucose except one side which is thinner and smooth.

II. Uredinia barely protruding through the epidermis, dehiscent by a central pore. Peridium hemispherical, delicate, cells longer at orifice. Spores borne singly on pedicels, obovate to ellipsoid; wall colorless, echinulate, pores indistinct.

III. Telia indehiscent, forming more or less evident layers in the epidermal cells or immediately beneath the epidermis. Spores oblong or prismatic, 2 to 4-celled by vertical partitions in two planes; wall smooth, colored.

Arthur [49] lists nine American species but none are very important.

P. hydrangeæ (B. & C.) Arth.

O and I. Unknown.

II. Uredinia hypophyllous, scattered, round, small, 0.1–0.2 mm. across, dark-yellow fading to pale-yellow, ruptured epidermis inconspicuous, dehiscent by a central pore; peridium hemispherical, delicate, cells small, cuboid, walls uniformly thin, 1–1.5 μ, ostiolar cells slightly or not elongate, 10-16 μ, barely pointed, walls thin, smooth; spores broadly elliptical or obovate, 12–18 x 16–24 μ; wall nearly colorless, thin, 1–1.5 μ, sparsely and strongly echinulate.

III. Telia amphigenous, or chiefly epiphyllous, effused, or confluent into small angular groups, 0.3–0.8 mm. across, not raised, reddish-brown; spores forming a single layer within the epidermal cells, or sometimes between the epidermis and mesophyll, globoid, 22–28 x 24–28 μ, wall dark cinnamon-brown, uniformly thin, 1.5–2 μ.

It is found in the uredinial and telial stages on Hydrangea on which it may be quite serious. [202]

P. gœppertianum (J. Kühn.) Kleb.

I. (=Æ. columnare) on Abies leaves. III on Vaccinium.

The æcial stage is the destructive form. It has been found

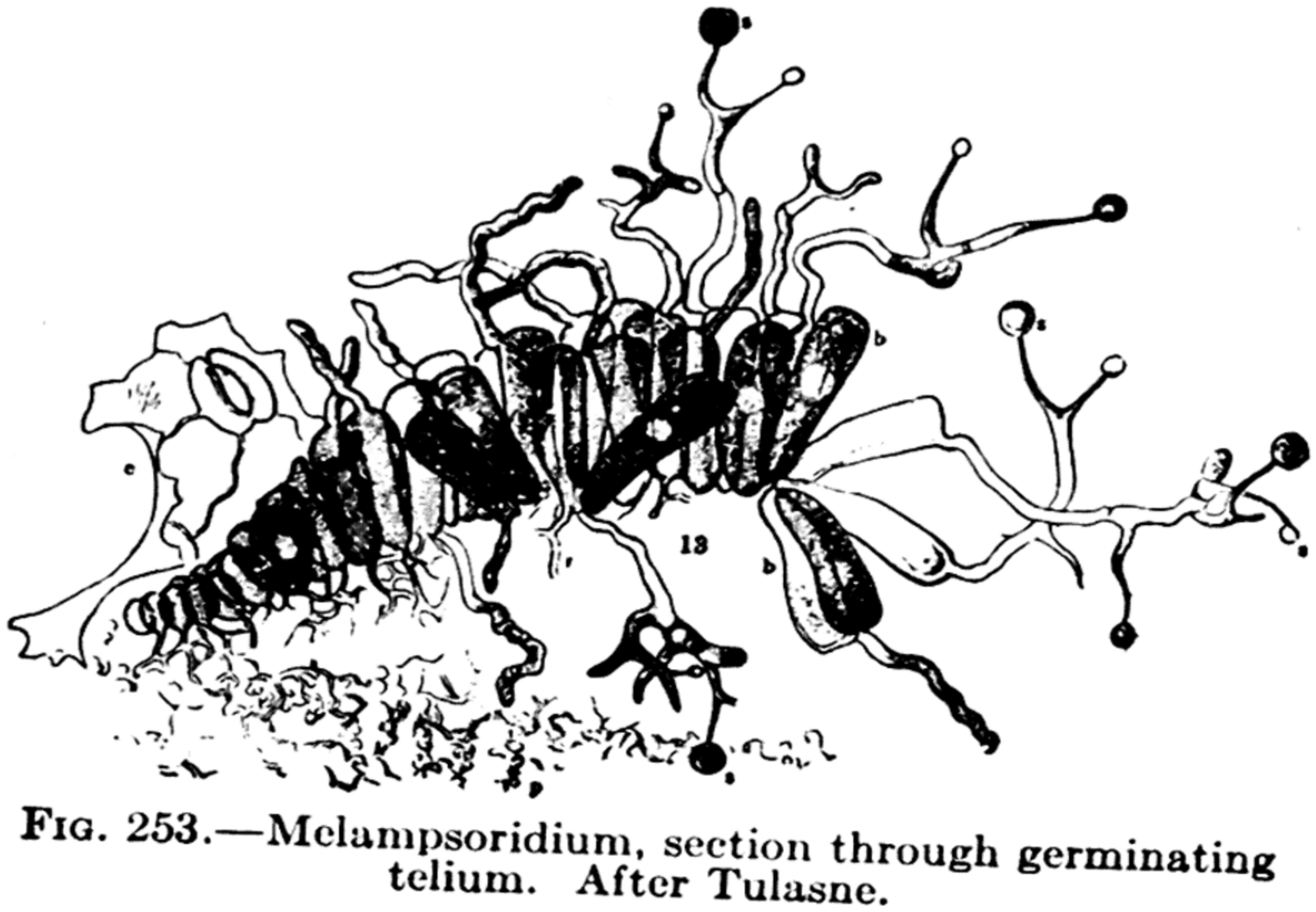


FIG. 253.—Melampsoridium, section through germinating telium. After Tulasne.

but a few times in America, [201, 310] while the telial stage is common. Fig. 252.

P. pustulatum (Pers.) Diet. (=**P. abieti-chamænerii, P. epilobii.**)

O and I on Abies. II and III on Epilobium.

P. padi (Kze. & Schm.) Diet.

I (=Æ. strobilinum) on fir.

II and III on Prunus padus.

P. myrtilli (Schm.) Arth. is found in the uredinial and telial stages on various Vacciniums.

Melampsoridium Klebahn (p. 341)

O. Pycnia flattened-conoidal, without ostiolar filaments.

I. Æcia erumpent, subcylindrical. Peridium regularly dehiscent, cells rhomboidal. Spores ellipsoid to globoid; wall colorless, thin, verrucose except one side which is thinner and smooth.

II. Uredinia somewhat erumpent. Peridium firm, dehiscent by central pore; peridial cells isodiametric, those of orifice pro-

longed into sharp points. Spores borne singly on pedicels, ellipsoid; wall colorless, echinulate, pores indistinct.

III. Telia indehiscent, forming evident layers immediately beneath the epidermis. Spores oblong or prismatic, 1-celled; wall smooth, slightly colored.

M. betulæ (Schüm.) Arth. occurs, O and I on larch, II and III on Betula.

Melampsorella Schröter (p. 341)

O. Pycnia hemispherical, without ostiolar filaments.

I. Æcia erumpent, definite, oblong, bullate. Peridium colorless, with thin-walled cells. Æciospores ellipsoid; wall colorless, thin, verrucose, without smooth spot.

II. Uredinia barely protruding through the epidermis, dehiscent by a central pore. Peridium hemispherical, delicate, cells slightly or not enlarged at orifice. Urediniospores borne singly on pedicels, obovate to ellipsoid; wall slightly colored, echinulate, pores obscure.

III. Telia effused, indehiscent. Teliospores globoid to ellipsoid, 1-celled; wall smooth, colorless, thin.

M. elatina (A. & S.) Arth.[204]

O. Pycnia epiphyllous, few, scattered, punctiform, inconspicuous, subcuticular, not extending much into walls of epidermis, depressed-hemispherical, small, 100–130 μ broad, 40–50 μ high.

I. Æcia from a perennial mycelium, dwarfing the young shoots, and forming witches' brooms, hypophyllous, forming two irregular lines, deep-seated, wholly dropping out of the substratum at maturity, roundish or irregularly oblong, large, 0.5–1 mm. across, bladdery, soon open by falling away of the upper part; peridium colorless, dehiscence irregular, cells with thin inner and outer walls; æciospores broadly ellipsoid, or nearly globoid, 14–18 x 16–28 μ; wall colorless, thin, 1–1.5 μ, closely and rather finely verrucose.

II. Uredinia amphigenous, scattered or somewhat grouped, small, round, 0.1–0.4 mm. across, orange-red when fresh, pale-yellow when dry; peridium hemispherical, dehiscent by a small central orifice, cells elongate at sides, polygonal above, inner and outer walls same thickness; urediniospores ellipsoid or obovoid,

12–18 x 16–30 μ; walls pale-yellow, rather thin, 1–1.5 μ; sparsely echinulate with short conical points.

III. Telia hypophyllous, on whitish or pale reddish spots; teliospores within the epidermal cells, 1-celled, short-cylindrical or polygonal, 13-20 μ broad; wall colorless, smooth, thin.

I (=Peridermium elatinum) on fir causing swelling, cankers and witches' brooms.

II and III on various members of the pink family.

All stages possess perennating mycelium. The æcial stage is of most economic significance, producing witches' brooms of various sizes. The æcia are formed only on the deformed needles of the witches' brooms.

Melampsoropsis (Schröter) Arthur (p. 341)

Cycle of development includes pycnia, æcia, uredinia and telia, with distinct alternating phases; heteræcious. Pycnia and other sori subepidermal.

O. Pycnia deep-seated, somewhat erumpent, flask-shaped.

I. Æcia erumpent, flattened laterally. Peridium firm, outer wall of cells greatly thickened and transversely striate, inner wall smooth. Æciospores ellipsoid to globoid; wall colorless, coarsely verrucose with deciduous tubercles.

II. Uredinia erumpent, pulverulent. Peridium very delicate, evanescent, sometimes wanting. Urediniospores catenulate, globoid to lanceolate; wall colorless, verrucose with somewhat deciduous tubercles, pores obscure.

III. Telia erumpent, definite, roundish, waxy becoming velvety. Teliospores catenulate, 1-celled, oblong or cuboid; wall colorless, thin, smooth.

M. rhododendri (D. C.) Arth.

Uredinial and telial stages on Rhododendrons; pycnial and æcial stages (=Æcidium abietinum) on Picea excelsa.

The pycnia appear on fir leaves in spring and about a month later the æcia. The æciospores germinate upon the Rhododendron. The mycelium perennates in its evergreen leaves and produces the uredinial and telial stages, the former of which serves for dissemination. The basidiospores infect the young fir leaves.

Chrysomyxa Unger (p. 341)

III. Teliospores formed of a series of superimposed cells, of which the lower are sterile, forming flat or slightly elevated, orange or reddish, waxy, crusts. Germination of the teliospore by a promycelium from each cell, which produces mostly four basidiospores.

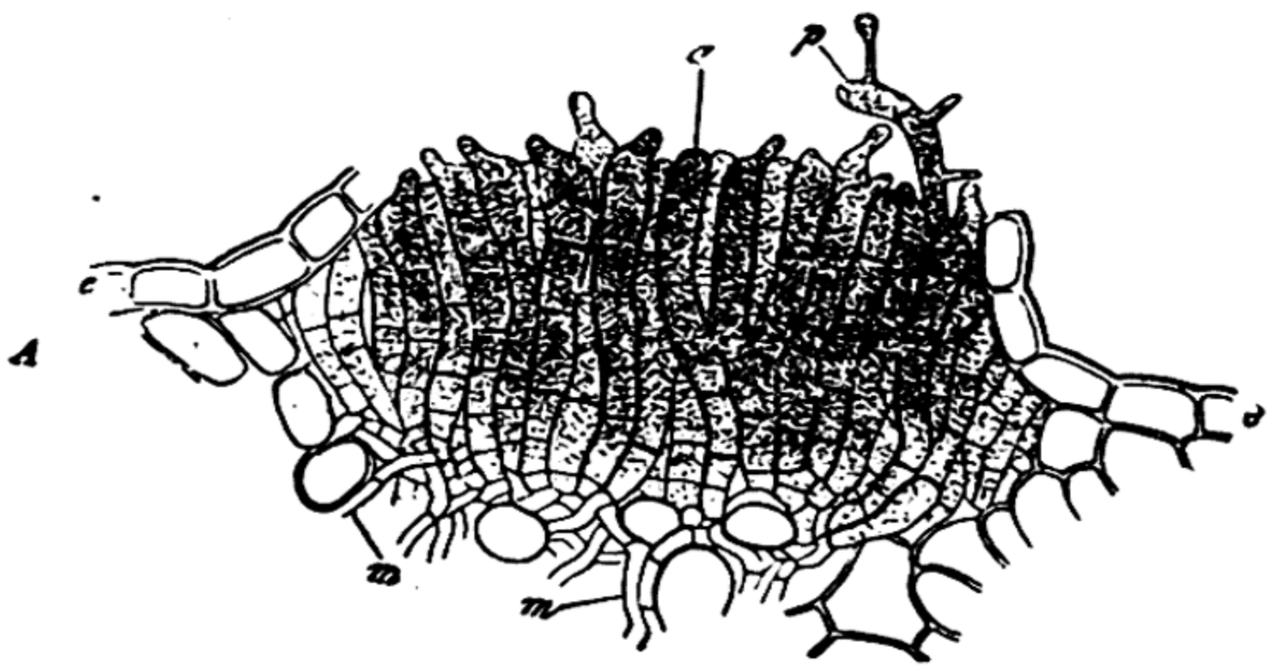


FIG. 254.—Melampsoropsis rhododendri, section through telium. After De Bary.

C. abietis (Wal.) Ung.

Telia only. It forms yellow spots on spruce leaves and the basidiospores seem able to infect the same host. European.

Cronartium Fries (p. 341)

O. Pycnia deep-seated, broad and flat.

I (=Peridermium). Æcia erumpent, inflated. Peridium membranous, rupturing at the sides rather than above, 2–4 cells thick, outer surface smooth, inner verrucose. Spores ellipsoid; wall colorless, coarsely verrucose with deciduous tubercles, except a smooth spot on one side.

II. Uredinia somewhat erumpent. Peridium moderately firm, rupturing above, upper part evanescent; peridial cells isodiametric. Spores borne singly on pedicels, globoid to ellipsoid; wall nearly or quite colorless, echinulate, pores obscure.

III. Telia erumpent, at first arising from the uredinia, the catenulate spores adhering to form a much extended, cylindrical or filiform column, horny when dry. Spores oblong to fusiform, 1-celled; wall slightly colored, thin, smooth.

Five American species are recognized by Arthur.[49]

All known æcial stages are Peridermiums on stems of conifers.

C. ribicola F. de Wal.[282–286, 297]

O. Pycnia caulicolous, scattered, honey-yellow, forming minute, bladdery swellings. Spores hyaline, ovoid to elliptical, 1.9–4.7 μ.

I (=Peridermium strobi). Æcia caulicolous, causing fusiform swellings of the stem, rounded to elongate; peridium inflated, rupturing at sides, thick, membranous. Spores ellipsoid to ovoid, 18–20 x 22–23 μ, wall colorless, coarsely verrucose except on elongate smooth spot, 2–2.5 μ thick, on smooth spot 3–3.5 μ thick.

II. Uredinia hypophyllous, thickly scattered in groups, round, pustular, 0.1–0.3 mm., at first bright yellow; peridia delicate.

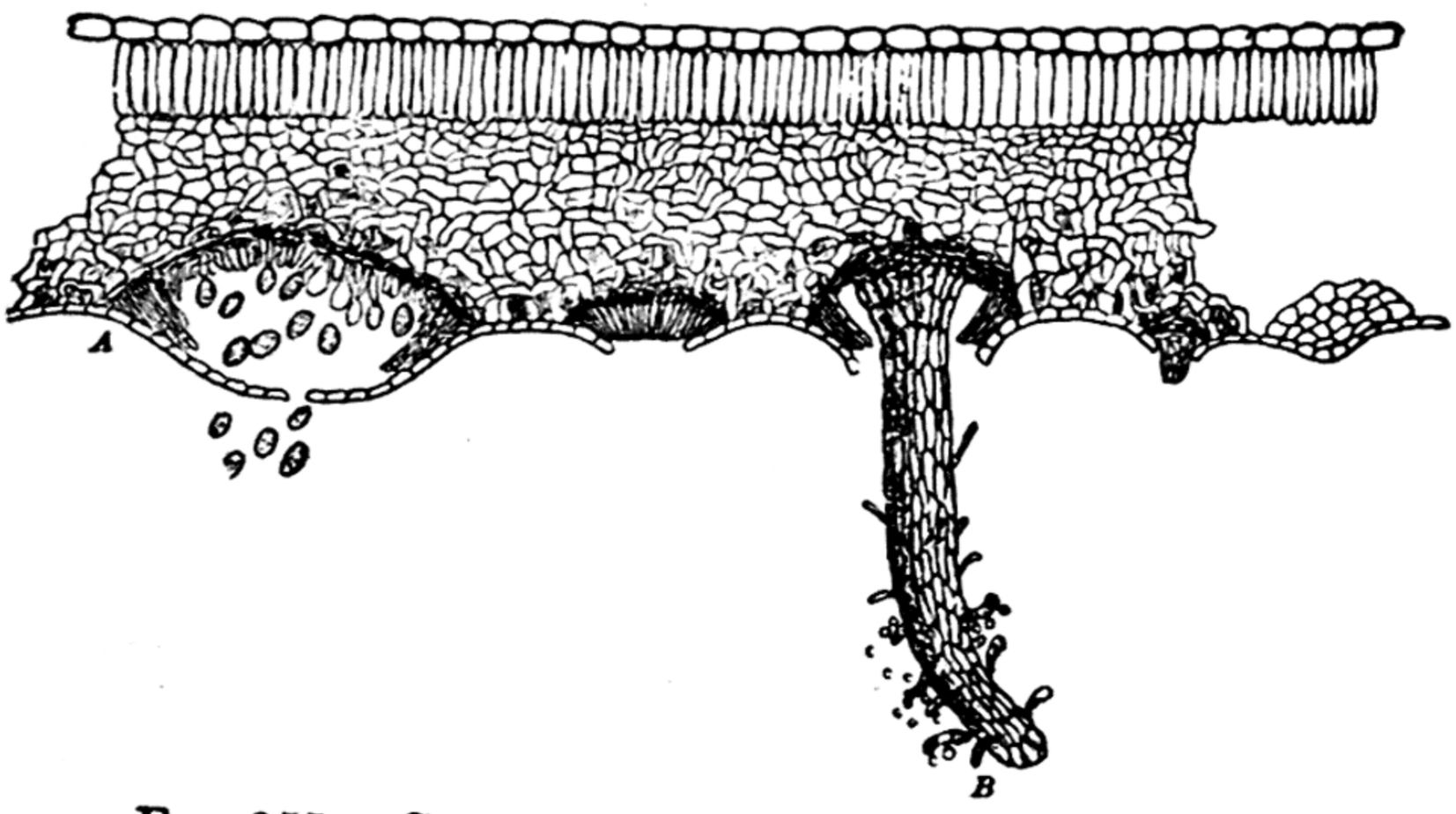


FIG. 255.—Cronartium. *A*, uredinium; *B*, telium. After Tubeuf.

Spores ellipsoid to obovate, 14–22 x 19–3.5 μ, wall colorless, 2–3 μ thick, sparsely and sharply echinulate.

III. Telial columns hypophyllous, cylindrical, 125-150 μ thick, up to 2 mm. long, curved, bright orange-yellow, becoming brownish; spores oblong or cylindrical, 8–12 x 30–60 μ; wall nearly colorless, smooth, rather thick, 2–3 μ.

Heteroœcious O, I, on white pine, Pinus cembra and several other 5-leaved species; II and III on currant and gooseberry and several other species of Ribes.

The telial stage was first noted in Geneva, N. Y., in 1906.[284] The rust is now known in some nine states. It has been known in Europe since 1854. Its effects are most serious in its æcial stage, though the telial stage is very abundant and conspicuous. The generic connections of the forms was proved by Klebahn in 1888 by inoculations.

The mycelium is doubtfully perennial in Ribes and certainly is so in the bark of the pine.

C. comptoniæ Arth.

I (=Peridermium pyriforme) on Pinus trunks. III on Comptonia.

The Peridermium is perennial in the trunks of the pine where it does considerable injury. Clinton sowed æciospores from pine



FIG. 256.—Cronartium comptoniæ (Peridermium) on Pinus. After Clinton.

on Comptonia and in about twelve days the uredinia began to appear.[197]

C. quercus (Brond.) Schr.

Heteræcious I (=Peridermium cerebrum) on pine. III on oak.

Successful inoculations were first reported by Shear,[288] later by Arthur and Hedgcock.[287] Globoid swellings 5–25 cm. across are formed on pine trees.

C. asclepiadeum (Wil.) Fries.

Heteræcious I (=Peridermium cornui) on Pinus silvestris.

II and III on Cynachum, Pæonia, Gentiana and several other hosts. European.

The mycelium is perennial in pine twigs and gradually kills them.

Endophyllum Léviellé (p. 342)

The cycle of development includes only pycnia and telia, both subepidermal.

O. Pycnia deep-seated, somewhat erumpent, flask-shaped, with ostiolar filaments.

III. Telia bullate, definite, round, pulverulent. Peridium evanescent, cells resembling spores but flattened. Spores catenulate or seemingly compacted without order, 1-celled, globoid to ellipsoid; wall colored, medium thick, verrucose.

E. sempervivi (Alb. & Schw.) D. By.

Pycnial and telial stages on species of Sempervivum. Mycelium perennial in the host.

Pucciniaceæ (p. 335)

Teliospores stalked (stalk sometimes short or evanescent) 1-celled or with several cells in a row or several united to form a parasol-like head on a compound stalk; separate or gelatinous-embedded. Basidiospores formed from promycelia. Æcia with or without peridia. Urediniospores solitary.

This is the largest and most important family of the order, infesting numerous valuable agricultural plants and causing enormous loss. The species are manifold and the complexities owing to polymorphism, heterœcism and biologic specialization are very great.

Key to Genera of **Pucciniaceæ**

Teliospores united into a head on compound pedicles, or several sessile or stalked on a common simple pedicel; sori subcuticular or subepidermal; uredinia when present without peridium or encircling paraphyses.	
Teliospores united into a head on a compound pedicel.	1. **Ravenelia.**
Teliospores free, 1–4 on a simple pedicel, all but one lateral	
Teliospores flattened laterally.	2. **Dicheirinia.**

Teliospores flattened above and below. . . . . 3. **Pileolaria.**
Teliospores not flattened, but uredinio-spores flattened laterally. . . . . 4. **Hemileia,** p. 355.
Teliospores free, 2–8 at apex of a common stalk
With all spore forms. . . . . 5. **Tranzschelia,** p. 356.
With pycnia and telia only. . . . . 6. **Polythelis.**
Teliospores not borne on a common pedicel, or united into heads.
Teliospore wall with a more or less evident gelatinous layer.
Teliospores with evident gelatinous layer, pores lateral
Teliospores 3-celled. . . . . 7. **Phragmopyxis.**
Teliospores 2-celled. . . . . 8. **Uropyxis.**
Teliospores with obscure gelatinous layer, pores apical.
Teliospores with appendaged pedicels. . . . . 9. **Prospodium.**
Teliospores without appendaged pedicels. . . . . 10. **Nephlyctis.**
Teliospore wall without gelatinous layer
Pycnia subcuticular, other sori subepidermal; æcia when present without peridium; uredinia when present without peridium, but usually with encircling paraphyses.
Teliospores mostly tuberculate, the pores more than one and lateral
Teliospores 1-celled. . . . . 11. **Trachyspora.**
Teliospores with 3 or more cells clustered at the apex of the pedicel
Teliospores 3-celled. . . . . 12. **Triphragmium,** p. 358.
Teliospores more than 3-celled . 13. **Sphærophragmium.**
Teliospores with more than three cells lineally arranged. . . . . 14. **Phragmidium,** p. 358.
Teliospores mostly smooth, the pores one in a cell and apical.
Teliospores 1-celled. . . . . 15. **Spirechina.**

Teliospores 2-celled	16. **Gymnoconia,** p. 359.
Teliospores 3 or more-celled.	
Without uredinia	17. **Xenodochus,** p. 361.
Without æcia	18. **Kuehneola,** p. 361.
Sori all subepidermal; æcia when present with a peridium; uredinia when present with no peridium or rarely with encircling paraphyses.	
Teliospores embedded in a more or less gelatinous matrix	19. **Gymnosporangium,** p. 361.
Teliospores not embedded in a gelatinous matrix.	
Teliospores colorless	20. **Eriosporangium.**
Teliospores colored	
Teliospores 1-celled	21. **Uromyces,** p. 371.
Teliospores 2-celled	22. **Puccinia,** p. 375.

Hemileia Berkley & Brown (p. 354)

Cycle of development imperfectly known; only uredinia and telia recognized, both subepidermal.

II. Uredinia formed beneath the stomata, erumpent, without peridium or paraphyses, spores borne singly on short pedicels, which arise from a protruding hymenium of agglutinated hyphæ, obovate, laterally flattened and dorsiventral; wall pale-yellow, smooth on ventral side, papillose on dorsal side, pores obscure or absent.

III. Telia replacing the uredinia. Spores borne singly on pedicels, 1-celled, napiform; wall nearly or quite colorless, smooth.

H. vastatrix Berk. & Br.

II. Hypophyllous, thickly scattered, or rarely somewhat circinate, very small, about 0.1 mm. across, light-orange fading to pale-yellow, pulverulent, projecting through stomata and rarely rupturing the epidermis; spores bilateral, slightly obovate, flattened on the ventral side, 20–28 by 30–40 μ; wall pale-yellow, 1–1.5 μ thick, rather thickly and very coarsely papil-

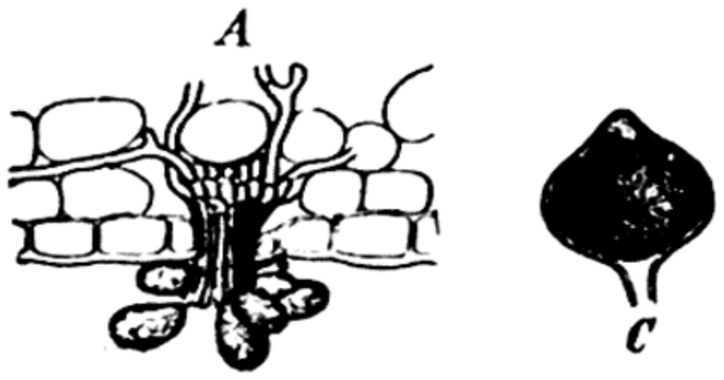


FIG. 257.—Hemileia vastatrix, *A*, uredinium; *C*, teliospore. After Dietel and Ward.

lose on dorsal side with bluntly pointed tubercles 2–4 μ long, 1–1.5 μ in diameter, ventral side smooth, pores obscure.

III. Hypophyllous, arising from uredinia, thickly scattered, very small, about 0.1 mm. across, pale-yellow; spores napiform or globoid, somewhat umbonate above; wall pale-yellow or seemingly colorless, thin, 1 μ, slightly if any thicker above, smooth; pedicel hyaline, one-half to once length of spore, slender.

It constitutes a serious coffee parasite in the orient and is reported also from Porto Rico.

H. woodii K. & C. is a serious coffee parasite and occurs also on Vanguieria edulis.

H. oncidii Griff & Maub. is on cultivated Oncidiums in France.

Tranzschelia Arthur (p. 354)

Cycle of development includes pycnia, æcia, uredinia and telia, with alternating phases; autœcious or heterœcious. Pycnia subcuticular, other sori subepidermal.

O. I. Pycnia depressed-conical or hemispherical; hymenium flat.

Æcia erumpent, cylindrical. Peridium dehiscent at apex, becoming recurved. Æciospores globoid; wall colored, finely verrucose.

II. Uredinia erumpent, definite, without peridium. Urediniospores borne singly on pedicels, with paraphyses intermixed, obovoid, somewhat narrowed at both ends; wall colored, usually paler below, echinulate; pores equatorial.

III. Telia erumpent, definite, pulverulent, without peridium. Teliospores forming heads or balls by being attached by short, fragile pedicels to a common stalk, which is short and inconspicuous, 2-celled by transverse septum, cells rounded and easily falling apart, wall colored, verrucose.

T. punctata (Pers.) Arth.[61, 294, 232, 233]

I (=Æcidium punctatum). Peridia uniformly scattered over the whole of the foliage, hypophyllous, flat, semi-immersed, with torn yellowish edges. Spores subglobose, pale yellowish-brown, 15–24 μ in diameter. Pycnia scattered, blackish, punctiform.

II. Uredinia light-brown, small, round, crowded, pulverulent, often confluent. Spores ovate or subpyriform, apex darker,

thickened, bluntly conical, closely echinulate, brown, 20–35 x 12–16 μ, mixed with numerous capitate brownish paraphyses.

III. Telia pulverulent, dark-brown, almost black. Spores consisting of two spherical cells, flattened at their point of union, the lower cell often being smaller and paler. Epispore uniformly



FIG. 258.—T. punctata, urediniospores. After Holway.

thick, chestnut-brown, thickly studded with short stout spines. Spores 30–45 x 17–25 μ. Pedicels short, colorless.

Heteræcious: O and I on Hepatica and Anemone.

II and III on Prunus sps., peach, almond, plum, cherry, apricot.

Widely distributed in North America, Europe and Asia and apparently introduced into Australia about 1883. The æcial stage is perennial. Urediniospores have also been shown to remain viable over winter. The peculiar character of the urediniospores has sometimes led this fungus to be mistaken for a Uromyces.

In 1904, Tranzschel [233] made cultures of the æcial stage from Anemone on various Prunaceous hosts. Arthur made similar inoculation from Hepatica in 1906.

Triphragmium Link (p. 354)

Teliospores 3-celled, one basal, two apical, each cell with one or more germ tubes.

T. ulmariæ Schm. occurs on Ulmaria in England and at one station in America.

Phragmidium Link (p. 354)

O. Pycnia present.

I. Æciospores in basipetal chains. The first two spore forms

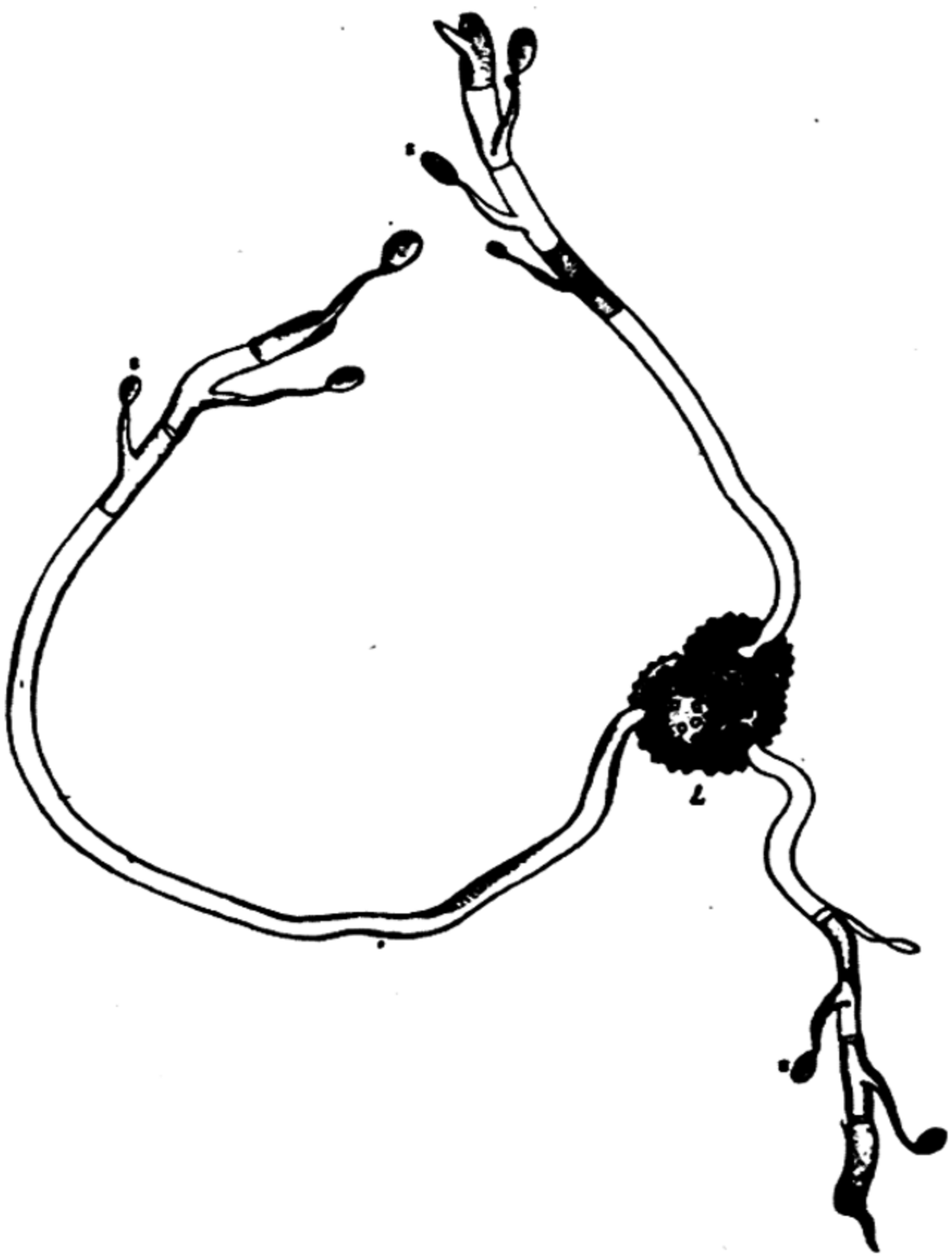


Fig. 259.—Triphragmium ulmariæ, germinating teliospore. After Tulasne.



Fig. 260.—Phragmidium bulbosum, teliospore germinating. After Tulasne.

are in pulverulent sori, surrounded by clavate or capitate, hyaline paraphyses.

II. Urediniospores single.

III. Teliospores separate, pedicellate, consisting of from three to ten superimposed cells, the uppermost of which has a single apical germ pore, the others about four each, placed laterally.

The æcial stage is a Cæoma but with a border of incurved pa-

raphyses. The unicellular urediniospores are similarly surrounded, and bear numerous germ pores. The genus is limited to Rosaceous hosts and its species are autœcious.

Eight American forms are recognized by Arthur [276] on roses as follows:

P. montivagum Arth., **P. disciflorum** (Tode) James, **P. americanum** Diet., **P. rosæ-setigeræ** Diet., **P. rosæ-californicæ** Diet., **P. rosæ-arkansanæ** Diet., **P. subcorticinum** (Schr.) Went. and **P. rosæ-acicularis Siro.**

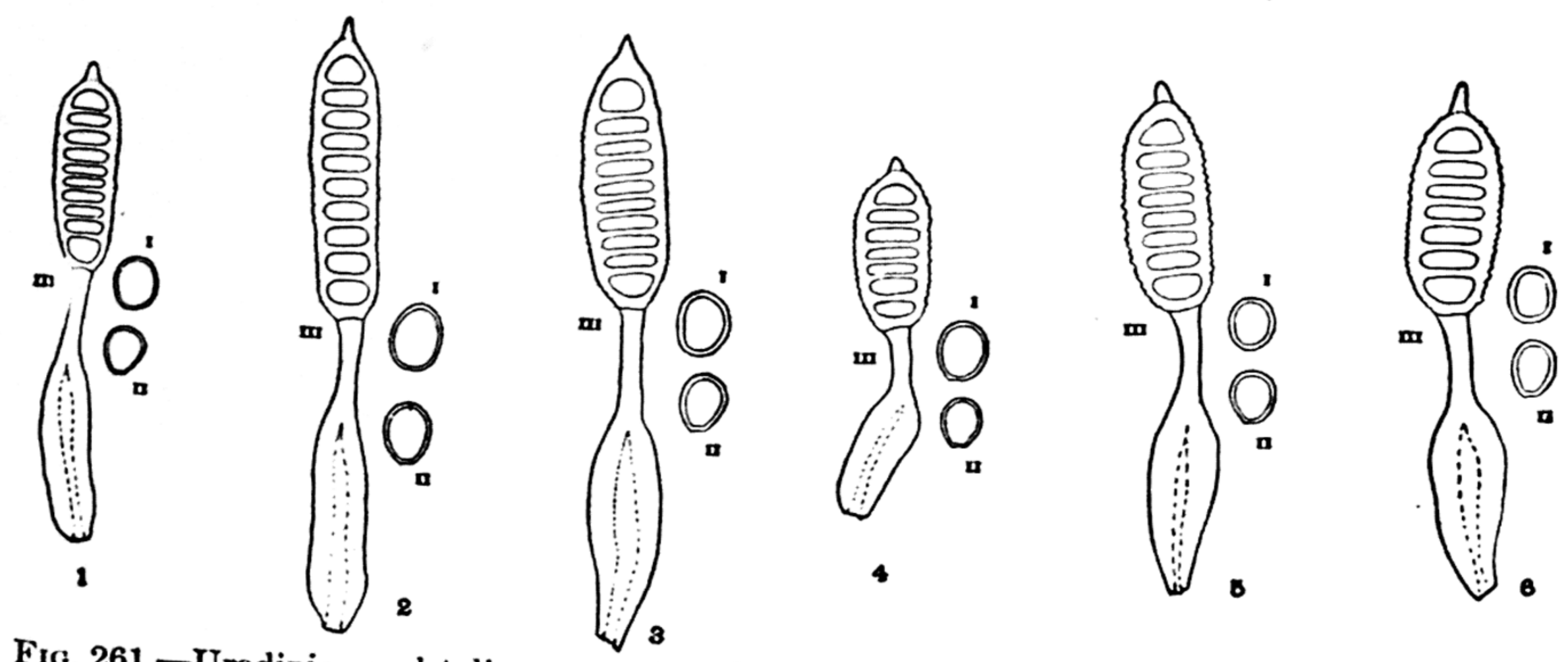


FIG. 261.—Uredinio- and teliospores of; 1. P. americanum; 2. P. rosæ-setigeræ; 3. P. rosæ californicæ; 4. P. rosæ-arkansanæ; 5. P. montivagum; 6. P. disciflorum. After Arthur.

They are mostly on wild roses and of but little economic importance.

P. violaceum (Schul.) Went. is often serious on Rubus in Europe.

P. rubi-idæi (Pers.) Wint. is found on raspberries in Europe.

P. speciosum Fr. on rose has been separated by Arthur as **Earlea speciosa** on account of its non-gelatinous teliospore pedicel, its large compact caulicolous telia and the absence of uredinia.

Gymnoconia Lagerheim (p. 355)

O. Pycnia conic.

I (=Cæoma), peridia and paraphyses none.

III. Spores as in Puccinia.

This genus bears a superficial resemblance to Puccinia but is easily distinguished by its naked æcial sori.

G. interstitialis (Schl.) Lag.[272-274, 211]

O. Pycnia glandular, numerous mostly epiphyllous.

I (=Cæoma nitens), hypophyllous, sori irregular, confluent; spores orange-red, globose to elliptic, epispore thin, 18–35 x 12–24.

III. Telia hypophyllous, few, sparse, cinnamon-brown; spores more or less angular, 36–45 x 22–27 μ, pedicel short or wanting.

Autœcious, on raspberries and blackberries, wild and cultivated, in United States, Canada, Europe and Asia.

The pycnial stage appears first in spring giving to the leaves and stems a glandular appearance. About two or three weeks

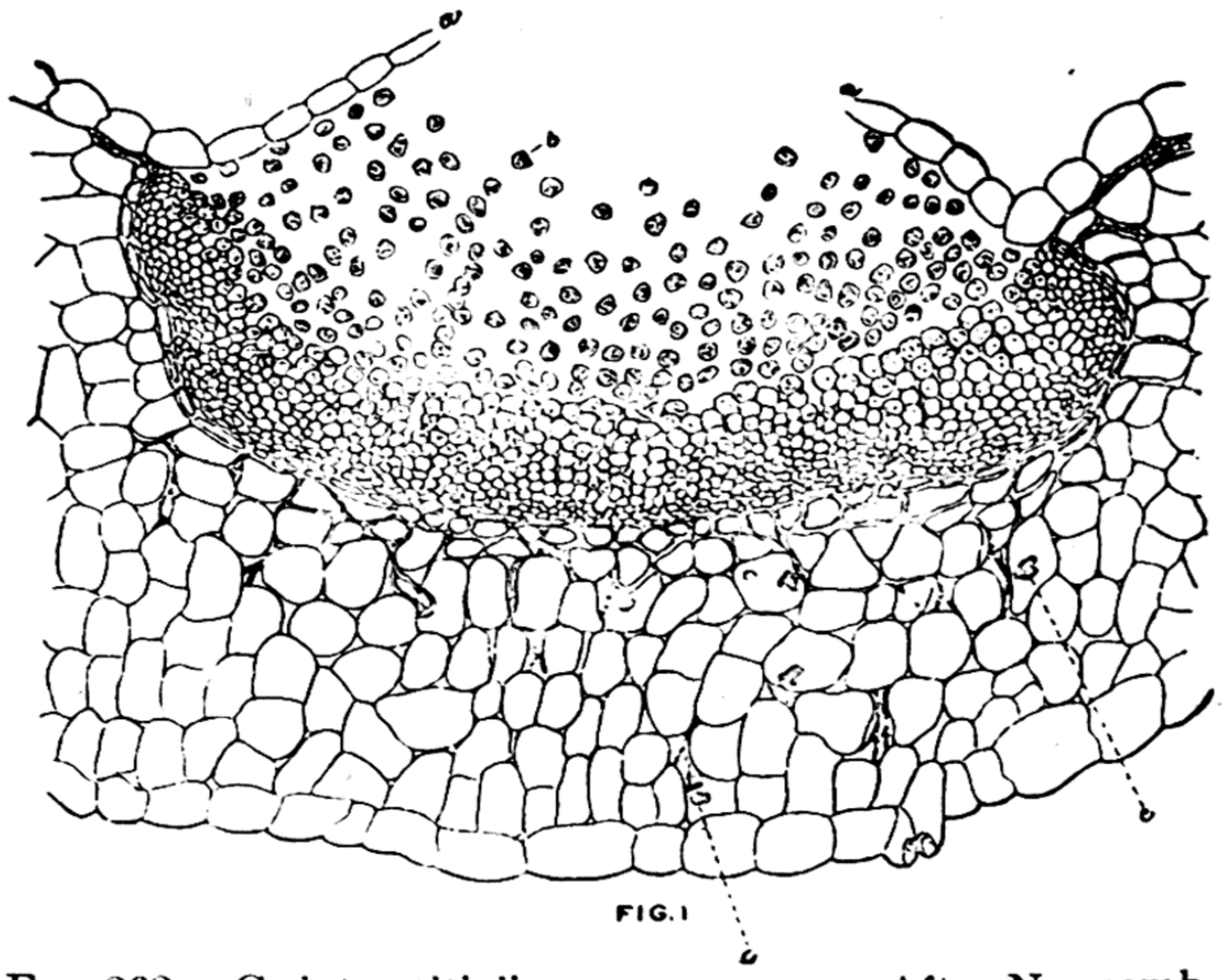


Fig. 262.—G. interstitialis, cæoma sorus. After Newcomb.

later the æcial stage is visible on the lower surface of the leaves; the epidermis soon ruptures and the orange beds of spores show. The pycnia are then fully developed. The affected plants are much stunted and are unproductive but are not killed. The fungous mycelium is intercellular, growing rapidly into formative tissues and perennating [273] in the woody shoots. The knob-like haustoria penetrate the cells and often lie against the nuclei. The mycelium is especially abundant in the pith near the bundles.

The æciospores may germinate at once and infect susceptible hosts. The teliospore which is less conspicuous and therefore rarely seen is of the Puccinia type. The telia appear in July

and August, usually hypophyllous, and the sori are very small and inconspicuous.

Artificial infection of Rubus with the spores of the Cæoma stage by Tranzschel [275] gave rise to the telial form, demonstrating the identity of the two. Cultures were also made by Clinton about the same time.

Xenodochus Schlecht (p. 355)

Æciospores catenulate; uredinia wanting; teliospores short-pedicelled, several celled in linear arrangement.

X. carbonarium Schl., autœcious on Sanguisorba in Europe.

Kuehneola Magnus (p. 355)

Æcia wanting; uredinia pulvinate, telia similar to Phragmidium but with smooth spores with the germ pores apical.

K. uredinis (Lk.) Arth.

II. (=Uredo muelleri.) Uredinia lemon-yellow, minute dots; spores globose to elliptic, about 26 μ, hyaline, slightly verrucose.

III. Telia solitary, pale, 250–500 μ broad; spores 5 to 6 to 12-celled, epispore hyaline, cells 17–47 x 15–26 μ; basidiospores 8.5-9.5 μ.

The telia are pale yellowish-white, thus readily distinguishing them from other Rubus rusts.

The uredinia are common and sometimes injurious on Rubus. The sori are small and scattered.

K. gossypii (Lagerh.) Arth. is reported on cotton in British Guiana,[279] also Florida, Cuba and Porto Rico.

Gymnosporangium Hedwig f.[206-211, 213, 217] (p. 355)

Cycle of development including pycnia, æcia and telia, with distinct alternating phases; heteræcious and autœcious. Pycnia and other sori subepidermal.

O. Pycnia deep-seated, usually globoid, generally prominent and conspicuous, at first honey yellow, usually becoming blackish, globose or flattened-globose, with ostiolar filaments.

I (=Rœstelia) erumpent, at first cylindric. Peridium dingy white, usually elongated into a tubular form, membranous, tending

to rupture by longitudinal slits along the sides; peridial cells imbricate and often articulated, occasionally hygroscopic, outer walls smooth, rather thin, inner walls smooth, verruculose, verrucose, rugose, or spinulose. Æciospores in basipetal chains with alternate barren cells, enclosed in a peridium, globoid to broadly ellipsoid; wall colored, verrucose, usually with numerous, scattered, evident germ pores.

III. Telia erumpent, naked, usually definite, variously shaped, gelatinous and elastic at maturity, expanding considerably when moistened. Teliospores chiefly 2-celled, in some species 3, 4, or

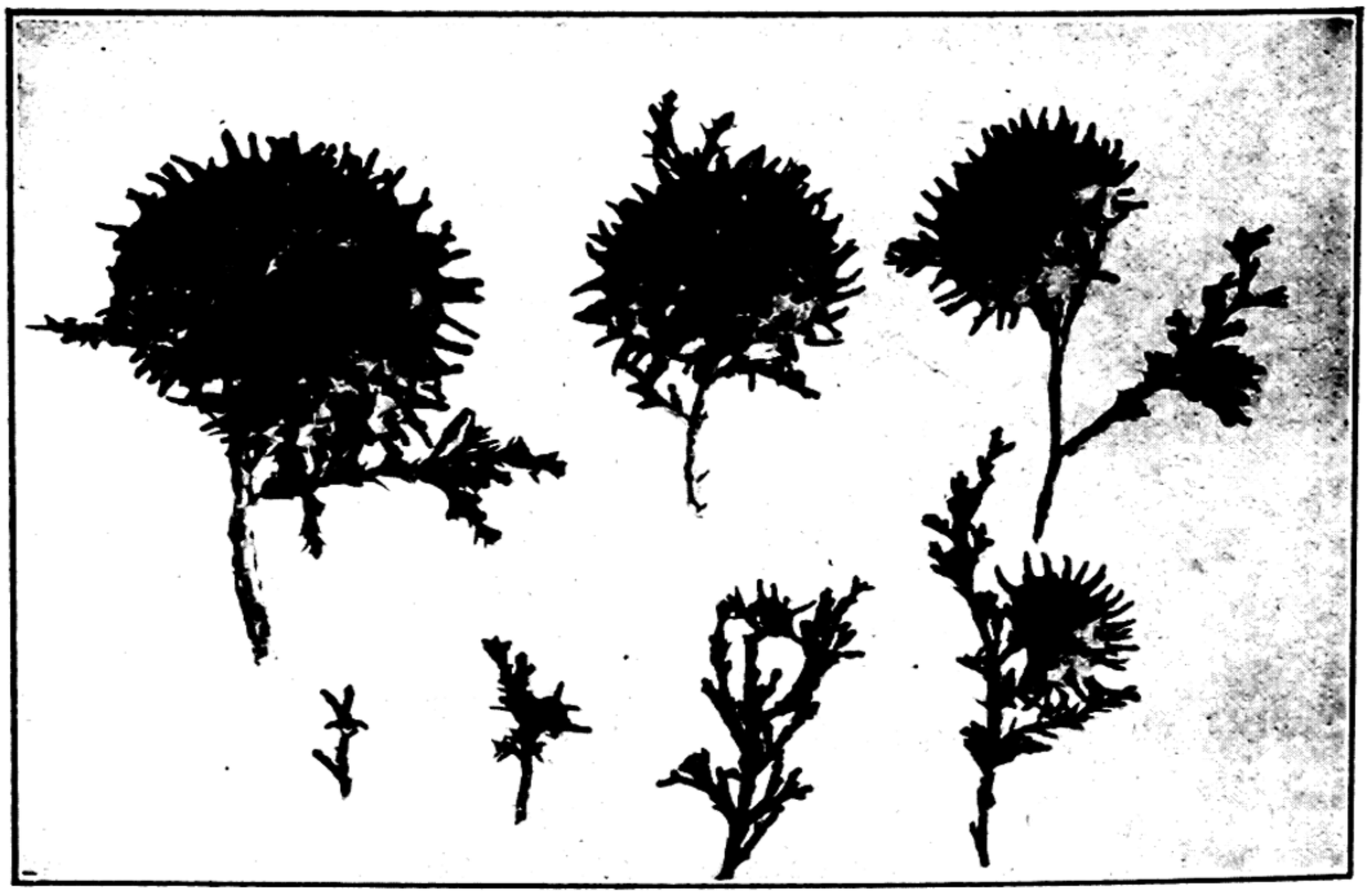


FIG. 263.—Gymnosporangium, spore masses just emerging. After Heald.

5-celled, by transverse septa; walls colored, of various thickness, smooth; pores usually two in each cell, sometimes, 1, 3, or 4, variously arranged; pedicels hyaline, elastic, usually of considerable length, cylindric, rarely carotiform, walls thick, the outer portion swelling and becoming gelatinous to form a jelly-like matryx in which the spores appear embedded.

All of the species agree in possessing the same spore forms, pycnia, æcia, and telia which appear in the same sequence in the different species; also, in the fact with two exceptions, that the æcia grow on pomaceous plants and the telia on Juniperus (with few exceptions).

The æciospores are borne in æcia which rest in orange or yellow spots often strongly thickened. Pycnia abound. The æcium with its thick peridium is erumpent and projects to some distance above the host surface, this character giving rise to the separate form-genus, Rœstelia. The peridial margin which may be lacerate or fimbriate is used in specific characterization. The spores are borne and function as in ordinary æcia. They bear several germ pores.

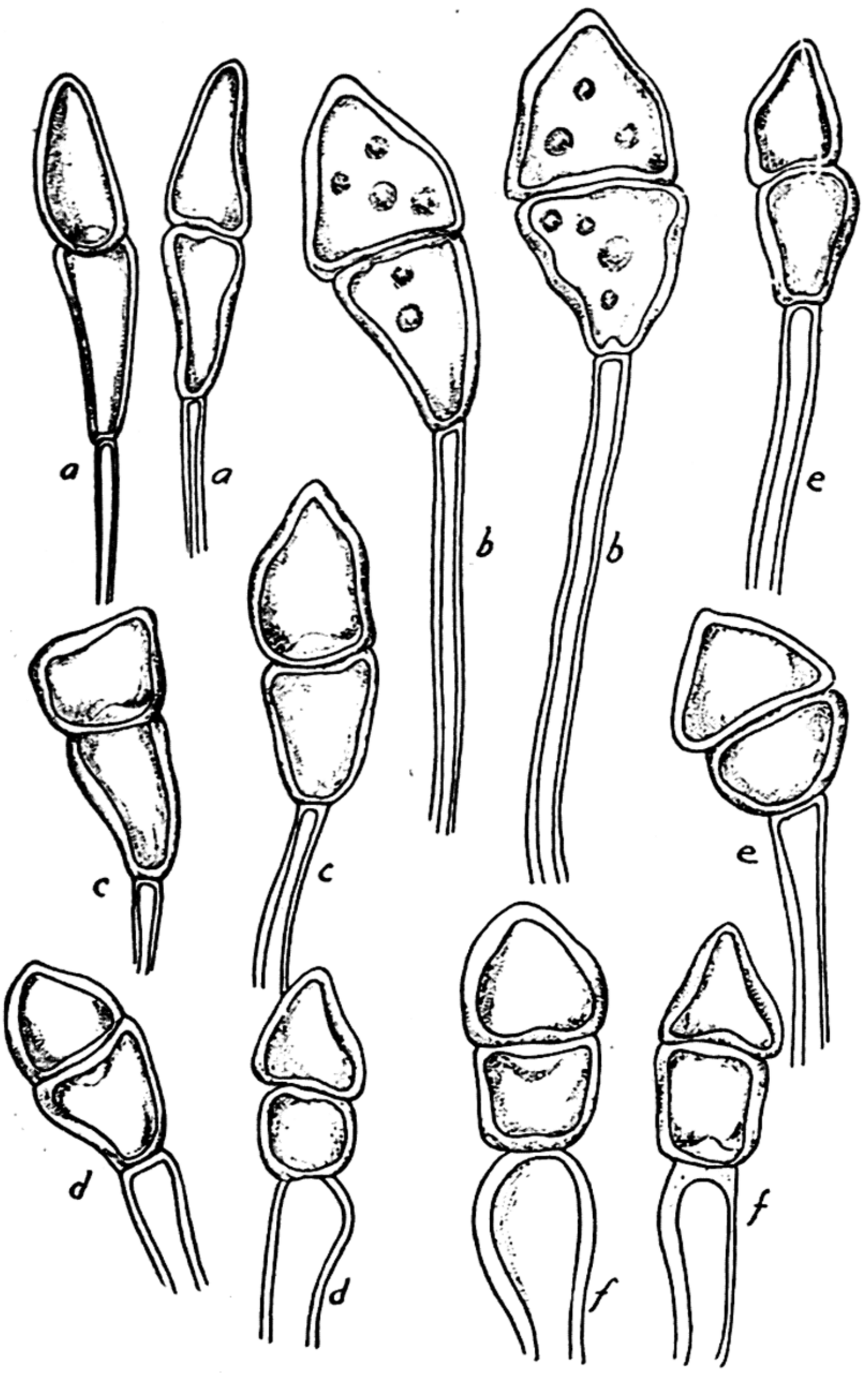


FIG. 264.—Gymnosporangium teliospores. *a*, G. clavariæforme; *b*, G. globosum; *c*, G. macropus; *d*, G. nidus-avis; *e*, G. nelsoni; *f*, G. clavipes. After King.

Æciospores germinate at once and if they fall upon suitable coniferous hosts bring about infection. The mycelium penetrating the leaf or branch often induces large hypertrophy.

In spring in moist weather the teliospores are found in spore masses composed of the spores, which are usually orange or yellow, and of their long gelatinous pedicels.

Each cell usually bears several germ pores near the septum through one of which the tube emerges.

The teliospores germinate immediately *in situ* by typical 4-celled promycelia and four basidiospores are produced on each promycelium.

The basidiospores are capable of infecting only the appropriate alternate host and that when the parts are still young and tender.

An abnormal development of germ tubes instead of the usual promycelium has been reported in some instances. According to Lloyd & Ridgway [302] several crops of basidiospores are produced in one season.

The various species usually make good subjects with which to study infection. The teliospore masses placed in water soon become covered with basidiospores. Suspensions of these in water applied to susceptible hosts usually give positive results readily.

G. juniperi-virginianæ Lk. [208, 213, 214](=G. macropus) Schu.

O. Pycnia epiphyllous.

I. Æcia (=Rœstelia pyrata) chiefly hypophyllous, usually in annular groups, on thickened discolored spots, at first cylindric, 0.1–0.4 mm. in diameter; peridium splitting extremely early, becoming fimbriate to the base, strongly revolute; peridial cells usually seen only in side view, long and narrow, 10–16 x 65–100 μ, becoming much curved when wet, inner and side walls rather sparsely rugose with ridges extending half way across the side walls; æciospores globoid or broadly ellipsoid, 16–24 x 21–31 μ, wall light chestnut-brown, 2–3 μ thick, finely verrucose.



FIG. 265.—G. juniperi-virginianæ, aecia. After Heald.

III. Telia appearing on globoid or reniform galls 5–30 mm. or more in diameter, evenly disposed, cylindric or cylindric-acuminate, 1.5–3 mm. in diameter by 10–20 mm. long, golden-brown; teliospores 2-celled, rhombic-oval or narrowly ellipsoid, 15–21 x 42–65 μ; slightly or

not constricted at the septum, wall pale cinnamon-brown, thin, about 1 μ; pedicel cylindric, 3–5 μ in diameter; pores two in each cell near the septum.

I. Æcia on apple both wild and cultivated.

III. Telia on Juniperus virginiana and J. barbadensis.

Destructive, particularly in East and South.

Sporidia are matured in twelve to twenty-four hours after the spore-masses expand by moisture and as soon as the sori begin to dry they are carried away by wind and on suitable hosts infect through the cell walls by appresoria. Two or three crops of sporidia may arise in one season but the first crop is largest.[214] Each crop may result in a corresponding crop of æcia. The stage on apple fruits shows as pale-yellow spots of pinhead size about seven to ten days after infection. The spots finally become orange-colored and in a few weeks the pycnia appear as black specks. On leaves hypophyllous cushions 0.5–1 cm. in diameter form on the spots and bear the æcia, the mature tubes of which are split and recurved giving a stellate appearance. Æciospores pass back to the cedar in summer and cause infection. The mycelium here remains practically dormant according to Heald [214] until the following spring when the telial galls first become visible. These galls grow throughout the summer, mature in the fall, and give rise to the teliospores during the next spring. The mycelium is thus seen to be biennial.

G. clavariæforme (Jacq.) D. C. [206, 208, 211]

I. Æcia hypophyllous, fructicolous or caulicolous, usually crowded in small groups 2–3 mm. across on the leaf blades, sometimes in larger groups on the veins, petioles and twigs, often densely aggregated on the fruits and occupying part or all of the surface, cylindric, 0.7–1.5 mm. high by 0.3–0.5 mm. in diameter; peridium soon becoming lacerate, usually to base, erect or spreading; peridial cells long and narrow, often becoming curved when wet, linear in face view, 18–30 x 80–13 μ, linear or linear-oblong in side view, 15–25 μ thick, outer wall 1–2 μ thick, smooth, inner wall and side walls 5–7 μ thick, rather coarsely verrucose with roundish or irregular papillæ of varying sizes; æciospores globoid, 21–27 x 25–30 μ, wall light cinnamon-brown, 2.5–3.5 μ thick, moderately verrucose.

III. Telia caulicolous, appearing on long fusiform swellings of various sized branches, numerous, scattered, or sometimes aggregated, cylindric, or slightly compressed, 5–10 mm. long by 0.8–1.5 mm. in diameter, acutish, or sometimes forked at the apex, brownish-yellow; teliospores 2-celled, lanceolate, 13–20 x 40–80 μ, occasionally longer, rounded or narrowed above, usually narrowed below, very slightly or not at all constricted at the septum, wall golden-yellow, thin, about 1 μ; pores 2 in each cell, near the septum.

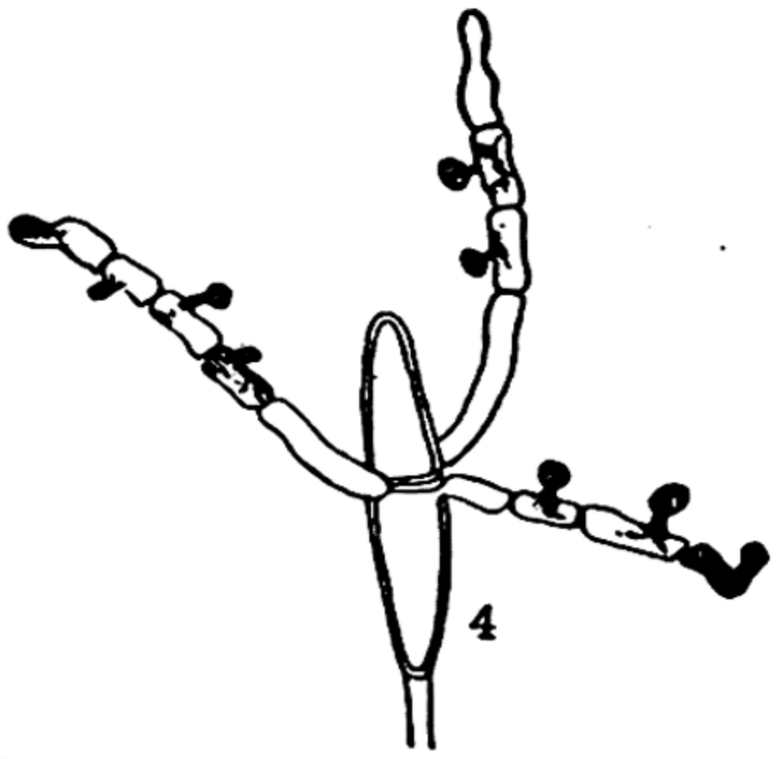


FIG. 266. — Gymnosporangium clavariæforme germinating teliospore. After Richards.

I. Æcia on Cratægus spp., Amelanchier, Aronia, Cotoneaster, Cydonia, and Pyrus.

III. Telia on Juniperus communis, J. oxycedrus, and J. sibirica. Spindle-shaped swellings occur on Juniper branches. Cylindric spore-masses ooze through rifts in the bark. Æciospores shed in June germinate at once on Juniper twigs and result in the following year in swellings which often later cause death. In spring the spore-masses emerge and the teliospores germinate *in situ*. Upon the Rosaceous hosts spots appear eight to fourteen days after infection. Kienitz-Gerloff reports the occasional formation of a germ tube instead of a promycelium. This is, however, to be regarded as an abnormal condition.

G. globosum Farl. [208, 213, 215, 216]

O. and I. Æcia chiefly hypophyllous and crowded irregularly or rarely in approximately annular groups 2–7 mm. across, cylindric, 1.5–3 mm. high by 0.1–0.2 mm. in diameter; peridium soon splitting in the upper part, becoming reticulate half way to base; peridial cells seen in both face and side views, broadly lanceolate in face view, 15–23 x 60–90 μ, linear rhomboid in side view, 13–19 μ thick, outer wall about 1.5 μ thick, smooth, inner and side walls 3–5 μ, thick, rather densely rugose with ridge-like papillæ of varying length; æciospores globoid or broadly ellipsoid, 15–19 x 18–25 μ, wall light chestnut-brown, 1.5–2 μ thick, finely verrucose.

III. Telia caulicolous, appearing on irregular globoid, gall-like

excrescences 3–25 mm. in diameter, unevenly disposed, often separated by the scars of the sori of previous seasons, tongue or wedge-shaped, 1.5–3 mm. broad by 2–5 mm. long at the base and 6–12 mm. high, chestnut-brown; teliospores 2-celled, ellipsoid, 16–21 x 37–48 μ, somewhat narrowed above and below, slightly constricted at the septum, wall pale cinnamon-brown, 1–2 μ thick; pores 2 in each cell, near the septum.

I. Æcia on apple, pear, Cratægus, quince, mountain ash.

III. Telia on Juniperus virginiana and J. barbadensis. Common and widely distributed in eastern America.

The telial galls are from 0.5 to 2.5 cm. in diameter, very irregular. In late spring dark-brown spore-masses, later yellow-orange, 0.5 to 2.5 cm. long appear.

The Rœstelia spots are 0.5–1.0 cm. across. Pycnia blackish above. The æcia are on thickened hypophyllous spots, long, slender, soon splitting and becoming fimbriate. Mesospores occur occasionally. The æciospores germinate on the cedar. The mycelium stimulates the hosts to extra formation of parenchymateous tissue.

G. juniperinum (L.) Mart.

I. Æcia (=Rœstelia penicillata [Pers.] Fries.) hypophyllous, in annular or crowded groups, 2–5 mm. across on large thickened discolored spots, at first cylindric, 0.5–1.5 mm. high, 0.5–1 mm. in diameter; peridium soon becoming finely fimbriate to base and somewhat twisted or incurved; peridial cells usually seen only in side view, rhomboid, very thick, 30–35 x 60–90 μ, outer wall medium thin, 2–3 μ, smooth, inner wall medium thick, 7–10 μ, rugose, side walls very coarsely rugose with thick, somewhat irregular ridges, roundish or elongate ridge-like papillæ interspersed; æciospores globoid, very large, 28–35 x 30–45 μ, wall chestnut-brown, thick, 3–5 μ, rather finely verrucose.

III. Telia caulicolous, appearing on hemispheric swellings (1–4 cm. long) breaking forth along the sides of the larger branches, or on subglobose galls (1.5–2 cm. in diameter) on the smaller branches, applanate, indefinite, usually of considerable size, often covering the whole hypertrophied area, sometimes becoming patelliform when expanded, chocolate-brown; teliospores 2-celled, ellipsoid, 18–28 x 42–61 μ, usually slightly narrowed both above

and below, slightly or not constricted at the septum, wall cinnamon brown, 1–1.5 μ, thick; pores usually 3 in upper cell, 1 apical, 2 near the septum, in the lower cell 2 pores near the septum.

O and I on apple and mountain ash.

III. Telia on Juniperus communis and J. sibirica. In Europe.

The teliospores occur on both twigs and leaves. Marked deformation is caused by this stage on leaves and petioles.

G. clavipes C. & P. [208] (=G. germinale [Schw.] Kern).

I. Æcia (=Rœstelia aurantiaca) on stems and fruits, crowded on hypertrophied areas of various size on the twigs and peduncles, occupying part or nearly all of the surface of the fruits, cylindric, 1.5–3 mm. high by 0.3–0.5 mm. in diameter; peridium whitish, becoming coarsely lacerate, sometimes to base, erect or spreading; peridial cells seen in both face and side views, polygonal-ovate or polygonal-oblong in face view, 19–39 x 45–95 μ, rhomboid in side view, 25–40 μ, thick, outer wall moderately thick, 3–5 μ, inner wall very thick, 13–23 μ, coarsely verrucose with loosely set, large, irregularly branched papillæ, side walls verrucose on inner half similar to inner wall; æciospores globoid, large, 31–32 x 24–39 μ, wall pale yellow, thick, 3–4.5 μ, rather coarsely verrucose with crowded slightly irregular papillæ.

III. Telia caulicolous, appearing on slight fusiform swellings, usually aggregated, roundish, 1–4 mm. across, often confluent, hemispheric, 1–3 mm. high, orange-brown; teliospores 2-celled, ellipsoid, 18–26 x 35–51 μ, roundish or somewhat acutish above, obtuse below, slightly or not constricted at the septum, wall yellowish, 1–2 μ thick, slightly thicker at the apex; pedicles cariotiform, 9–19 μ in diameter near the spore; pores one in each cell, apical in the upper, near the pedicel in the lower.

I. Æcia on Amelanchier, Aronia, Cratægus, Cydonia, and apple.

III. Telia on Juniperus communis and J. sibirica.

G. cornutum (Pers.) Arth.

A rather uncommon species with I (=Rœstelia cornuta [Pers.] Fries) on Sorbus spp. and III on Juniperus communis and J. sibirica. Ranging from New York to Wisconsin and northward; also in the mountains of Wyoming and Colorado: Europe. Of no considerable economic importance in America.

G. ellisii (Berk.) Farl.

I. Æcium unknown. III. Telia on Cupressus thyoides. Probably of very small economic importance.

G. transformans (Ellis) Kern. (=Rœstelia transformans Ellis).

I. Æcia on Pyrus arbutifolia, which is of no economic importance. Confined to a small area from Massachusetts to New Jersey.

III. Telia unknown.

G. nidus-avis Thax. [208, 217]

I. Æcia amphigenous, especially fructicolous, cylindric, 2–4 mm. high by 0.4–6.7 mm. in diameter; peridium soon becoming irregularly lacerate usually to base, slightly spreading; peridial cells, seen in both face and side views, lanceolate in face view, 15–23 x 55–88 μ; linear in side view, 14–18 μ, thick, outer wall 1–.5 μ thick, smooth, inner and side walls 5–7 μ thick, coarsely rugose with narrow ridges, with shorter, often roundish papillæ interspersed; æciospores globoid or broadly ellipsoid, 18–23 x 23–28 μ, wall cinnamon-brown, rather thick, 2.5–4 μ, very finely verrucose, appearing almost smooth when wet.

III. Telia caulicolous, often dwarfing the young shoots and causing birds' nest distortions, or witches' brooms, usually causing a reversion of the leaves to the juvenile form, sometimes appearing on isolated areas on the larger branches and producing gradual enlargements, solitary or rarely confluent, of variable size and shape, roundish to oval on the young shoots, 1–2 mm. across, oval to nearly elliptic on the woody branches, 1.5–3 mm. wide by 2–7 mm. long, pulvinate when young, becoming hemispheric, dark reddish-brown; teliospores 2-celled, ellipsoid, 16–23 x 39–55 μ, wall pale cinnamon-brown, rather thin, 1–1.5 μ, very slightly thicker at apex; pores one in a cell, apical. Mycelium perennial in leaves, branches or trunks of Juniperus virginiana very commonly inducing a "bird's nest" distortion.

I. Æcia on Amelanchier and quince.

III. Telia on Juniperus virginiana.

G. sabinæ (Dicks) Wint.

O and I (=Rœstelia cancellata), on pear in Europe.

III. Telia on several Junipers.

The telial mycelium is perennial and causes swellings. From these in spring ooze the gelatinous, transparent spore-masses.

The mycelium in Juniperus causes increase in wood-bast and rind, thickened twisted tracheids, increase in number and thickness of the medullary rays. No mycelium is found in the wood itself.

G. biseptatum Ell.

I. Æcia (=Rœstelia botryapites) hypophyllous, usually in groups of 2–8, rarely solitary, borne in gall-like pyriform protuberances 1–1.5 mm. in diameter by 1.5–3 mm. high, cylindric, 0.5–0.8 mm. in diameter by 2–4 mm. high; peridium soon becoming finely cancellate, not dehiscent at apex; peridial cells cylindric, hyphal-like, 9–14 μ in diameter by 145–190 μ long, often irregularly bent, outer, inner, and side walls of equal thickness, about 1.5–2 μ, whole surface smooth; æciospores globoid, small, 15–17 x 16–22 μ, wall dark cinnamon-brown, rather thick, 2.5–3 μ, moderately verrucose.

III. Telia caulicolous, appearing on fusiform swellings, scattered, oval or irregular, about 1.5–3 mm. wide by 2–7 mm. long, often confluent, hemispheric, chestnut-brown; teliospores 2 to 4-celled, 13–19 x 35–77 μ, usually rounded above, somewhat narrowed below, slightly constricted at the septa, wall pale-yellow, 1.1–5 μ thick, pores 2 in each cell, near the septa.

I. Æcia on Amelanchier.

III. Telia on Chamæcyparis.

G. nelsoni Arthur. Æcia hypophyllous and fructicolous, usually in small groups 1–2 mm. across, cylindric, 2–4 mm. high by 0.2–0.3 mm. in diameter; peridium whitish, dehiscent at apex and also rupturing more or less along the sides; peridial cells seen in both face and side view, 18–35 x 75–115 μ, linear rhomboid in side view, 16–35 μ, thick, outer wall rather thin, 1.5–2 μ. smooth, inner and side walls rather thick, 7–12 μ, evenly and densely verruculose; æciospores globoid, 19–26 x 21–29 μ, wall chestnut-brown, 2–3 μ thick, finely verrucose.

III. Telia caulicolous, appearing on firm, woody, globose galls 0.5–5 cm. in diameter, unevenly disposed, densely aggregated or often separated by the scars of the sori of previous seasons, irregularly flattened, about 1–1.5 mm. broad by 1–5 mm. long at the

base by 3–4 mm. high, often confluent, light chestnut-brown; teliospores 2-celled, narrowly ellipsoid, 18–26 x 50–65 μ, narrowed at both ends, slightly constricted at the septum; wall pale cinnamon-brown, 1–1.5 μ thick; pores two in each cell, near the septum.

I. Æcia on Amelanchier, Peraphyllum, quince and pear.
III. Telia on Juniperus spp.
Range; Alberta, south to Colorado and Arizona.

G. japonicum Syd. [218]

I. Æcia (=R. koreænsis), on Pear.
III. Telia on Juniperus.
This form has been imported into America.

G. torminali-juniperinum (Ed.) Fischer.

This species has its æcial stage on species of Sorbus and its telia on Juniperus in Europe. It is closely related to G. cornutum of the northern part of our own continent, and of Europe.

G. yamadæ Miyabe. Only the æcia of this species have been found. It infests the apple and various other species of Malus in Japan.

Uromyces Link (p. 355)

O. Pycnia spherical with minute ostioles.
I. Æcia with peridia, spores without pores.
II. Urediniospores generally with many germ pores, unicellular, spherical, ellipsoid or variously shaped, usually rough.
III. Teliospores unicellular, pedicellate, with an apical germ pore.

The unicellular teliospores may be distinguished from urediniospores by their single apical germ pore, also usually by their thicker walls and absence of the roughness so characteristic of urediniospores.

The genus is a very large one, with hundreds of species, which exhibit heterœcism, autœcism, biologic specialization and the various types regarding spore forms that are noted on pages 324–327.

U. appendiculatus (Pers.) Lév.[219]

I. Æciospores angularly globose, whitish, slightly punctulate

17–32 x 14–20 μ. II. Urediniospores pale-brown, aculeolate, 24–33 x 16–20 μ. III. Teliospores elliptical or subglobose, smooth, dark-brown, apex much thickened, with a small, hyaline, wart-like papilla, 26–35 x 20–26 μ.

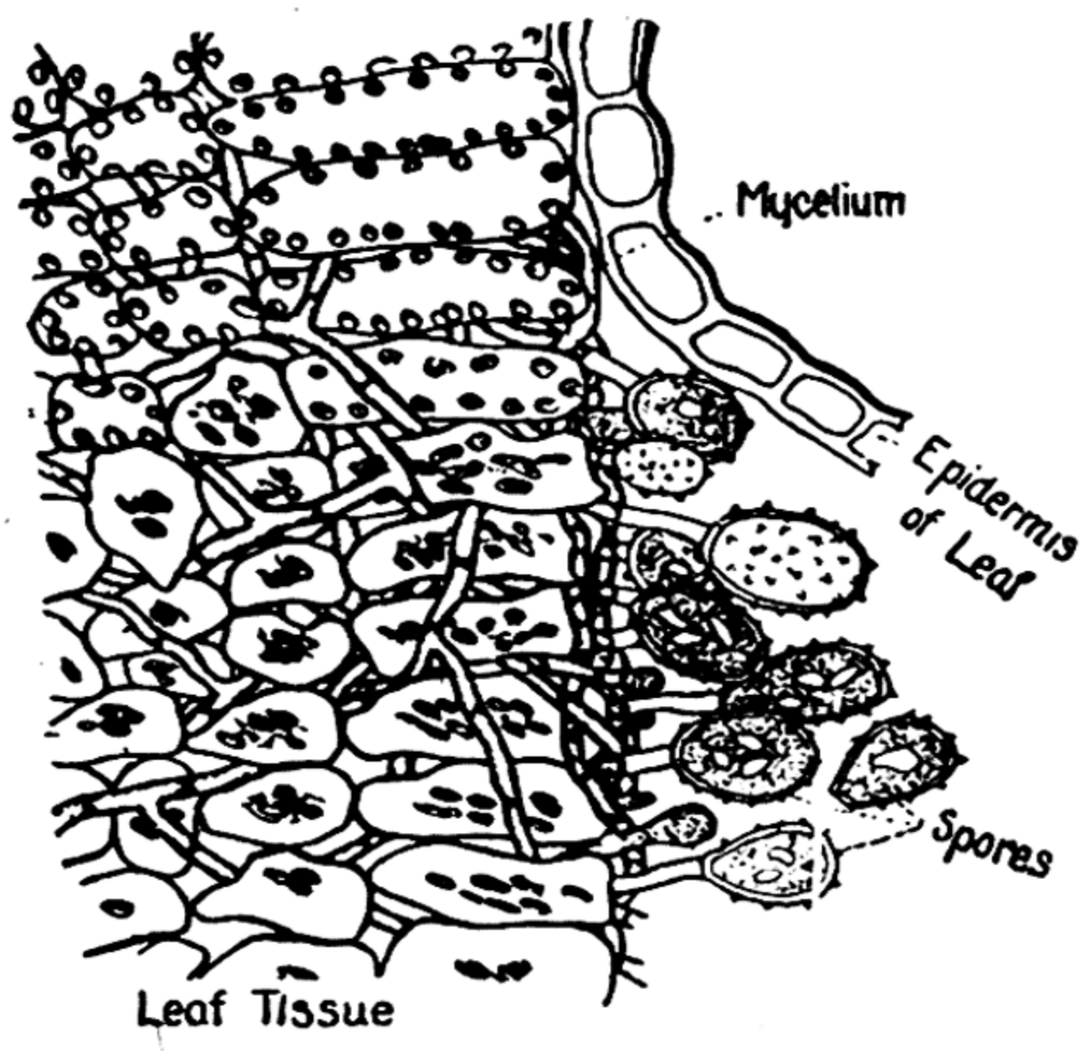


FIG. 267.—Diagrammatic section of uredinium of U. appendiculatus. After Whetzel.

An autœcious eu-type. On Phaseolus, Dolichos and other related legumes.

The sori usually appear late in the season on leaves, rarely on stems and pods. The mycelium is local. Great difference in varietal susceptibility is noted.

U. pisi (Pers.) de B.[59]

I. (=Ædidium cyparissiæ). Æcia scattered over the whole leaf surface. Peridia cup-shaped, with whitish edges. Spores subglobose or polygonal, orange, finely verrucose, 17–26 μ in diameter.

II. Uredinia roundish, scattered or crowded, cinnamon-brown. Spores subglobose or elongate, yellowish-brown, echinulate, 17–20 x 20–25 μ.

III. Telia roundish or elliptical, blackish. Spores subglobose or shortly elliptical, finely but closely punctate, apex only slightly thickened, 20–30 x 17–20 μ. Pedicels long, colorless, fragile.

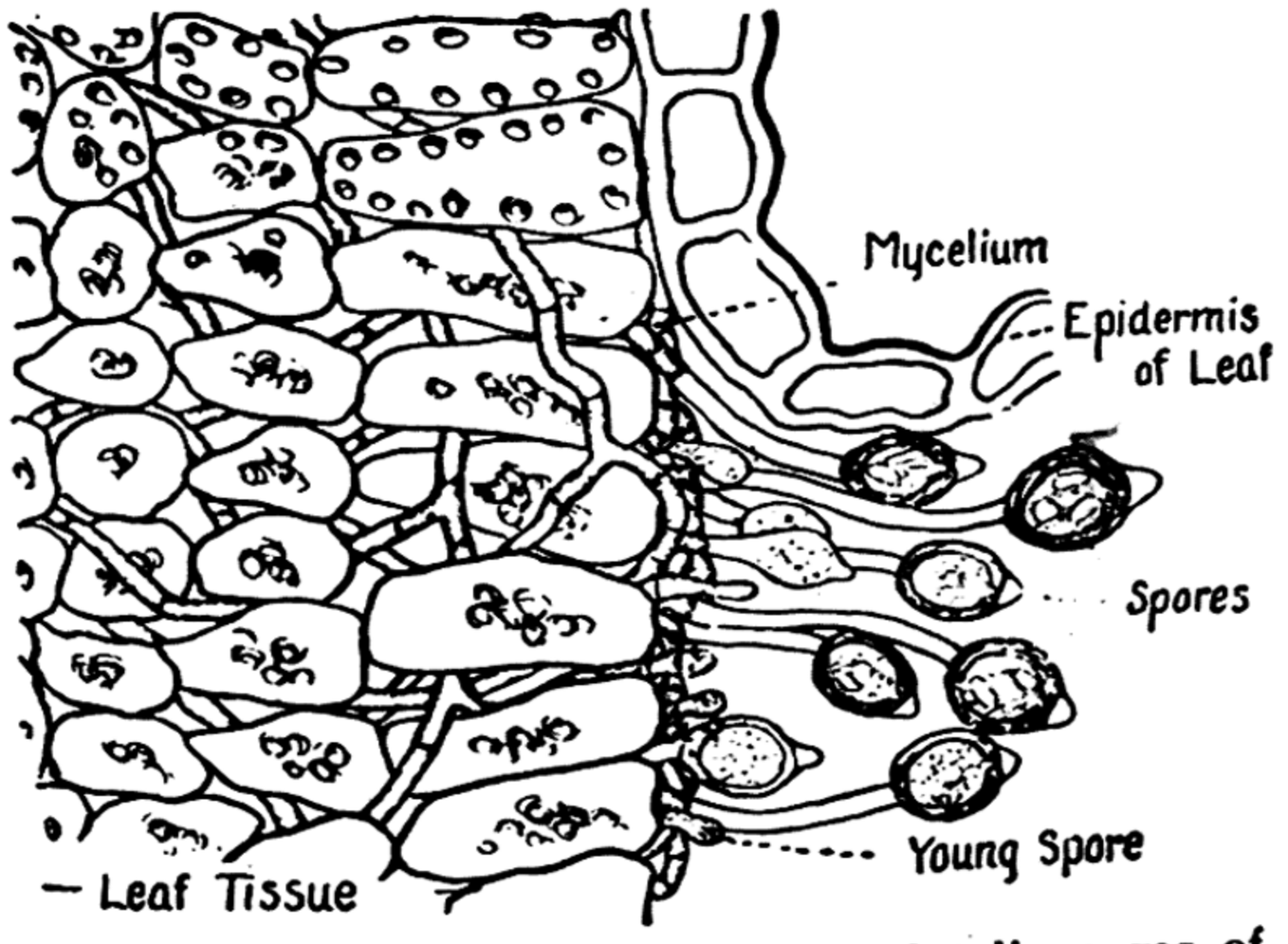


FIG. 268.—Diagrammatic section of teliospores of U. appendiculatus. After Whetzel.

A heterœcious eu-type not found in America: O and I on Euphorbia.

II and III on Lathyrus, Pisum, Vicia.

The æcial stage dwarfs the host in which it is perennial.

U. fabæ (Pers.) De B.[220] This is an autœcious eu-type which causes a rust of the broad bean, vetches, peas.

U. trifolii (Hed.) Lev.[221-223] An autœcious eu-type.

I. Æcia in circular clusters, on pallid spots. Peridia shortly cylindric, flattish, on the stems in elongated groups; edges whitish, torn. Spores subglobose or irregular, finely verrucose, pale-orange, 14–23 μ in diameter.

II. Uredinia pale-brown, rounded, scattered, surrounded by the



FIG. 269.—Uromyces appendiculatus, teliospore germinating. After Tulasne.



FIG. 270.—Urediniospore and teliospore of Uromyces trifolii. After Cobb.

torn epidermis. Spores round or ovate, with three or four equatorial germ pores, echinulate, brown, 20–26 x 18–20 μ.

III. Telia small, rounded, almost black, long covered by the epidermis. Spores globose, elliptical or subpyriform, with wart-like incrassations on their summits, smooth, dark-brown, 22–30 x 15–20 μ. Pedicels long, deciduous.

Cosmopolitan on white, crimson and alsike clovers. Stages O and I are most common on Trifolium repens, least common on T. incarnatum. Pycnia appear in early spring or even in winter. The æciospores germinate readily in water and give infections which give rise to urediniospores in about two weeks. Urediniospores may be produced throughout the summer and may even survive the winter. Teliospores are produced in the uredinia or in separate sori late in the season. The teliospores by infection

give rise to the pycnial and æcial stages. Considerable distortion arises in parts affected by either stage.

U. fallens (Desm.) Kern.[223] A form on crimson, zig-zag and red clover often confused with the last species.

O and I unknown.

II. Urediniospores with fou. to six scattered germ pores.

III. Teliospores similar to those of U. trifolii.

U. medicaginis Pass.

O and I. Pycnia and æcia as in U. pisi.

II. Uredinia chestnut-brown, spores globose to elliptic, 17–23 μ, light-brown.

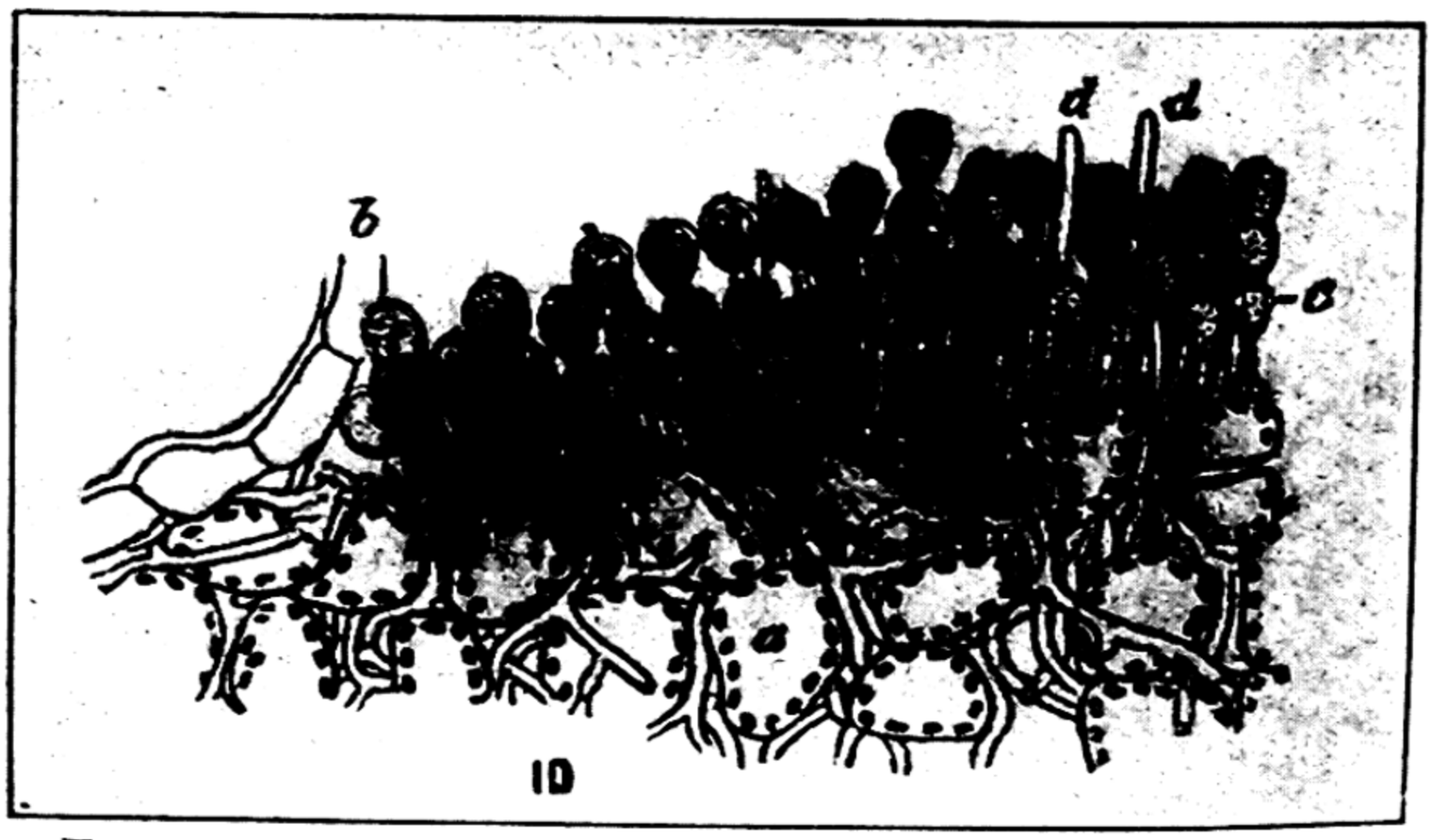


FIG. 271.—Uredo stage of U. betæ. After Scribner.

III. Telia dark-brown, spores ovate-elliptic or pyriform 18–28 x 14–20.

A heterœcious eu-type. I, on Euphorbia; in Europe.

II and III on alfalfa and clovers in Europe and America.

U. minor Schr. is an autœcious opsis-type, I and III on Trifolium montanum.

U. betæ (Pers.) Tul.[56, 291] An autœcious eu-type; on members of the genus Beta both wild and cultivated. In the United States observed only in California. Recorded in Europe, Africa, Australia.

U. kuhnei Krug. occurs on sugar cane.[225]

U. dactylidis Otth. is a heterœcious eu-type; II and III on Phleum, I on Ranunculus, in Europe.

U. poæ Rab. is a heterœcious eu-type; I on Ranunculus and Ficaria; II and III on Poa.

U. caryophyllinus (Schr.) Wint.[226-229]

I. Æcia on Euphorbia in Europe.

II. Uredinia sparse, confluent on stems, spores round, elliptic or oblong, 40 x 17–28 μ, light-brown.

III. Teliospores globose, irregular or ovoid, apex thickened 23–35 x 15–22 mm., pedicel 4–10 μ.

II and III on cultivated carnations and several other members of the genus Dianthus. I on Euphorbia gerardiana. It has been known in Europe since 1789 but was not noted in the United States until 1890 when it was found by Taft at Lansing, Mich. It soon invaded the whole country causing great loss. There is large racial difference in host susceptibility.

The urediniospores germinate readily in water and serve to propagate the fungus. Studies of the effects of toxic substances upon these have been made by Stevens [230] and by Stewart.[227] The æcial stage has recently been recognized by Fischer [323] as Æ. euphorbiæ-gerardianæ.

Less important species are: **U. ervi** (Wallr.) Plow. an autœcious eu-type on Vicia in Europe; **U. erythronii** (D. C.) Pass. an opsis-type occasional on cultivated Lilium in Europe. **U. ficariæ** Schw. is on Ficaria; **U. pallidus** Niess. a lepto-type on Cytisus; **U. scillarum** (Grev.) Wint. a micro-type on Scilla and Muscari. **U. jaffrini** Del. is reported on vanilla; [231] **U. colchici** Mas. on Colchinum speciosum in Europe.

Puccinia Persoon (p. 355)

O, I, II, as in Uromyces.

III. Teliospores separate, pedicellate, produced in flat sori, consisting of two superimposed cells each of which is provided with a germ pore. The superior cell has its germ pore, as a rule, piercing its apex; in the inferior or lower the germ pore is placed immediately below the septum.

Mesospores (p. 327) are not rare. They are merely teliospores with the lower cell wanting, and function as teliospores.

Some one thousand two hundred twenty-six species are enumerated by Sydow [60] presenting great diversity in spore relation, hetercœcism and biologic variation.

P. cerasi Ces. is a hemi-type on cherries in Southern Europe.

P. ribis-caricis Kleb.

I on Ribes. II and III on Carex.

Klebahn [234] differentiates five species of Puccinia on Ribes belonging to the Ribis-Carex group. These are P. pringsheimiana (I.=Æ. grossulariæ.) P. ribis-pseudocyperi, P. ribis nigri-acutæ, P. ribis nigri-paniculatæ and P. magnusii.

P. asparagi D. C.[235-240]

I. Peridia in elongated patches upon the stems and larger branches, short, edges erect, toothed. Spores orange-yellow, round, very finely echinulate, 15–26 μ in diameter.

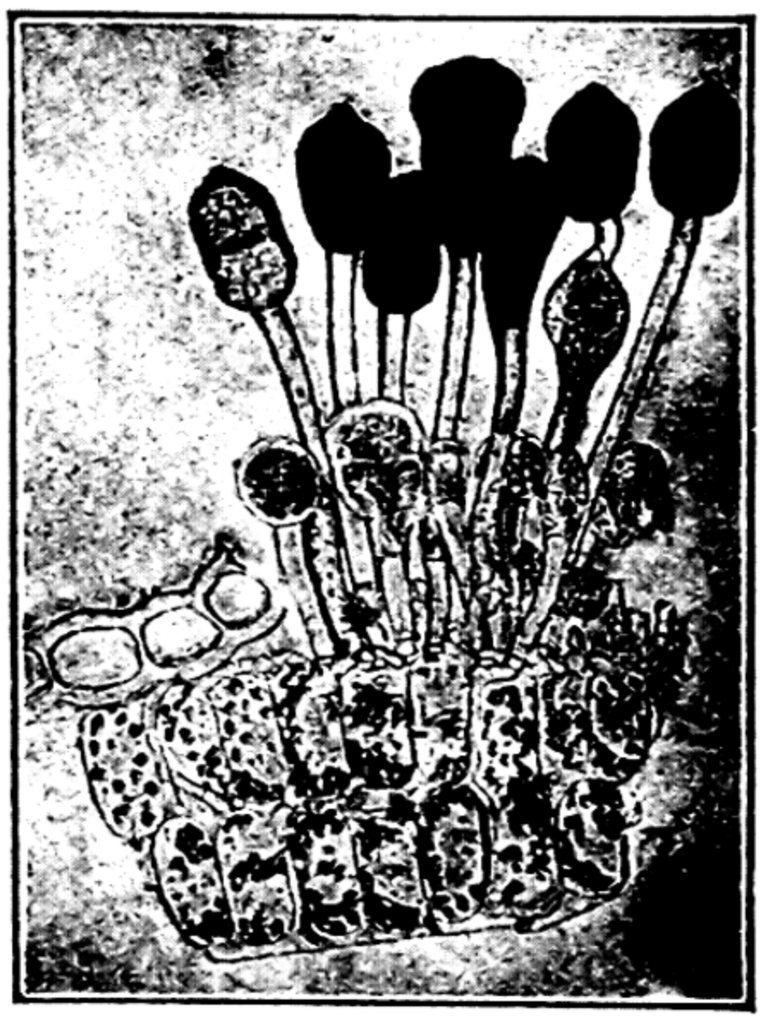


FIG. 272.—Section through black rust pustule, showing teliospores of P. asparagi. After Smith.

II. Uredinia brown, flat, small, long covered by the epidermis. Spores irregularly round or oval, clear-brown, echinulate. 18–25 x 20–30 μ.

III. Telia black-brown, compact, pulvinate, elongate or rounded, scattered. Spores oblong or clavate, base rounded, apex thickened, darker, central constriction slight or absent, deep chestnut-brown, 35–50 x 15–25 μ. Pedicels persistent, colorless or brownish, as long as or longer than the spores.

An autœcious eu-type on Asparagus, cultivated and wild. The fungus has been known in Europe since 1805 but did not attract attention in the United States until 1896 in New Jersey [235] when it began its devastating westward migration [241] across the country reaching California in 1900 or 1901.

The æcial stage appears in early spring; the æciospores may germinate at once or if dry remain viable for several weeks, their germ tubes penetrating the host in most cases stomatally. The uredinia appear in early summer soon after or with the æcial stage and, wind borne, distribute the fungus. The urediniospores remain viable a few months when dry. The telial stage appears late in the season and germinates only after hibernation.

Unicellular spores, mesospores, are sometimes met.

P. bullata (Pers.) Schr. is a brachy-puccinia which is autœcious on celery, parsley, dill and other umbellifers.

P. apii (Wallr.) Cda. also occurs in its uredinial and telial stages on celery.

P. castagnei Thüm is recorded for celery in France.

P. allii (D. C.) Rud. is a hemi-type on cultivated onions.

P. porri Sow. is an autœcious rust which is sometimes destructive to onions in Europe.

P. endiviæ Pass.[242] occurs on endive in Italy and America.

P. phragmitis Schum.[243-244]

I (=Æ. rubellum). Peridia on circular red spots 0.5–1.5 cm. in diameter, shallow, edges white, torn. Spores white, subglobose, echinulate, 15–16 μ in diameter.

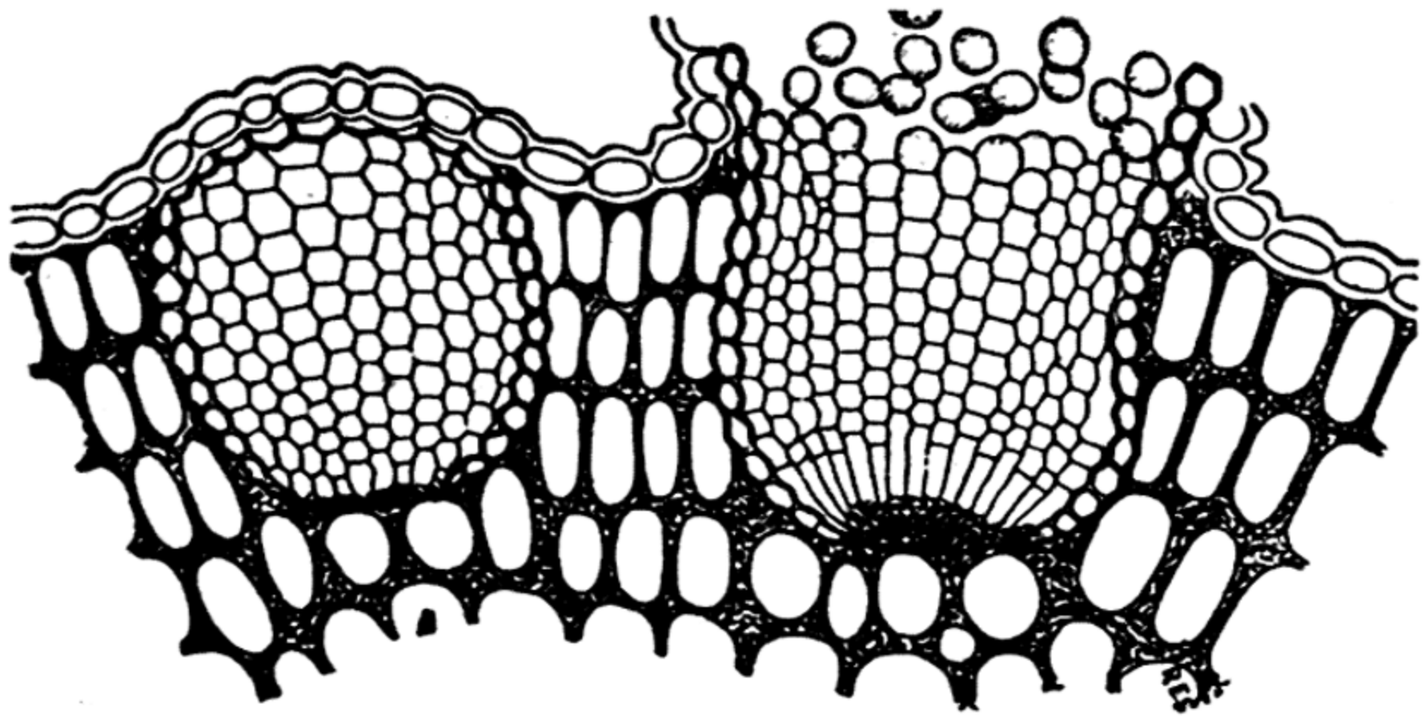


FIG. 273.—Cross-section of æcia of P. asparagi. After Smith.

II. Uredinia rather large, dark brown, elliptical, pulverulent, without paraphyses. Spores ovate or elliptical, echinulate, brown, 25–35 x 15–23 μ.

III. Telia large, long, sooty black, thick, often confluent. Spores elliptical, rounded at both ends, markedly constricted in the middle, dark blackish-brown, smooth, 45–65 x 16–25 μ. Pedicels very long, 150–200 x 5–8 μ, yellowish, firmly attached.

Heterœcious; I on Rumex and rhubarb, II and III on Phragmitis. Found only rarely in America,[243, 244] except in the middle west.

P. cyani (Schl.) Pass. is on cultivated Centaurea.

P. tragopogonis (Pers.) Cda.

I. Æcia on the whole plant—leaves, stems, bracts, receptacles—shortly cylindrical, at first mammæform, peridia with whitish, torn edges. Spores rounded, verrucose, orange-yellow, 18–27 μ, sometimes as much as 35 μ long. Mycelium diffused throughout the host-plant.

III. Telia brown, few, small, scattered, elliptical or elongate,

long covered by the epidermis. Spores broadly oval, often almost globose, slightly constricted, apex not thickened, thickly verrucose, brown, 26–48 x 30–35 μ. Pedicels short, colorless, deciduous. Mycelium localized.

An opsis-type on cultivated Tragopogon. Urediniospores are unknown. The teliospores are often unicellular and are very variable.

P. taraxaci Plow. is common on dandelion. **P. cichorii** Pass. is a hemi-type on Cichorium. **P. isiacæ** on Phragmitis is thought to be

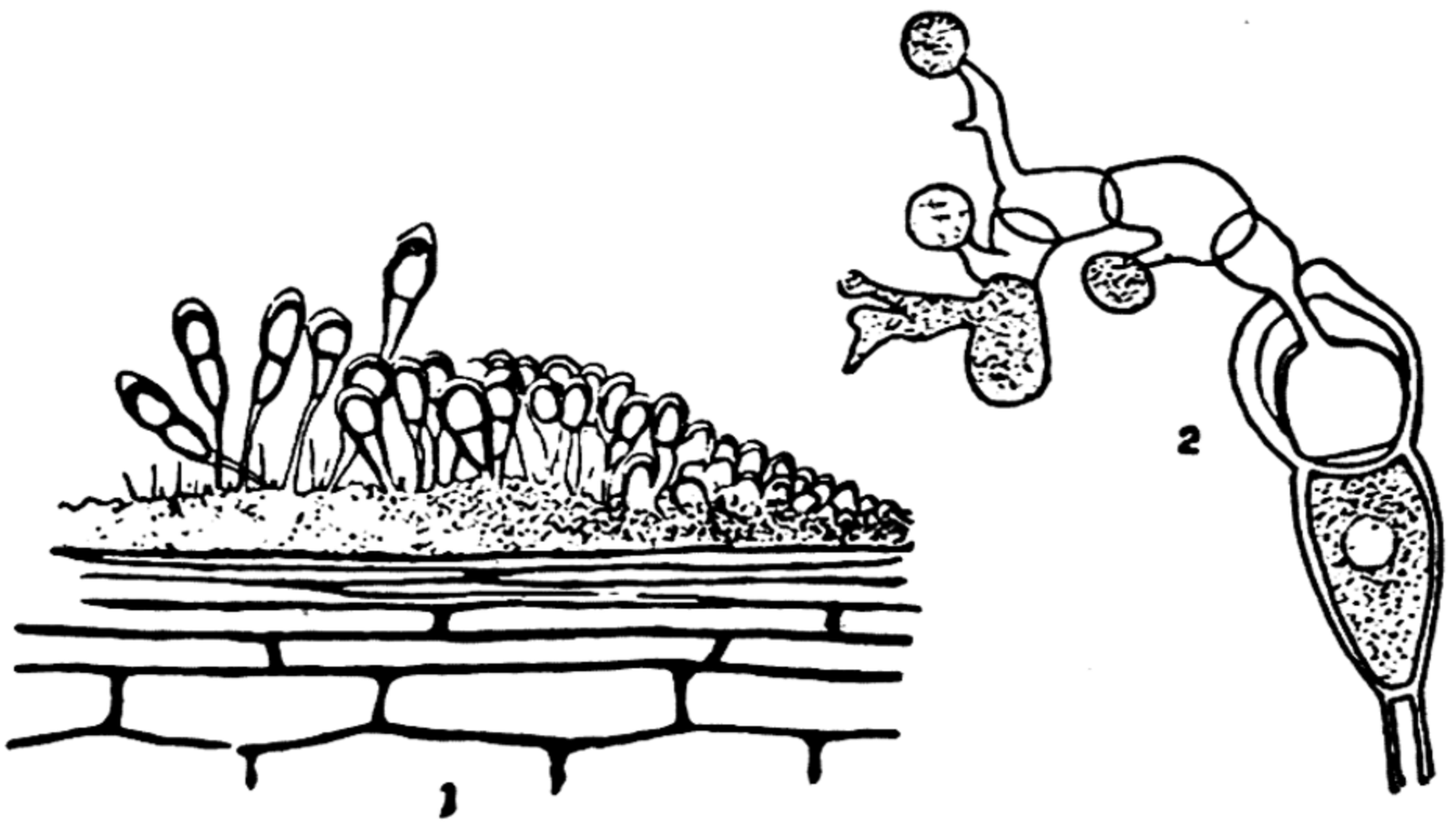


FIG. 274.—P. graminis, telium and germinating teliospore. After Carleton.

the telial stage of Æ. brassicæ on cabbage. [245] **P. fagopyri** Barcl. is found on buckwheat.

P. menthæ Pers. [300]

I. Æcia with peridia immersed, flat, opening irregularly, edges torn; principally on the stems, which are much swollen, more rarely on concave spots on the leaves. Spores subglobose or polygonal, coarsely granular, pale-yellowish, 17–26 x 26–35 μ.

II. Uredinia small, roundish, soon pulverulent and confluent, cinnamon-brown. Spores irregularly rounded or ovate, echinulate, pale-brown, 17–28 x 14–19 μ.

III. Telia black-brown, roundish, pulverulent. Spores elliptical, oval, or subglobose, central constriction slight or absent, apex with a hyaline or pale-brown papilla, verrucose, deep-brown, 26–35 x 19–23 μ. Pedicels long, delicate, colorless.

An autœcious eu-type on many mints.

P. graminis Pers. [45, 166–182, 246, 306, 322]

I (=Æ. berberidis). Spots generally circular, thick, swollen, reddish above, yellow below. Peridia cylindrical, with whitish torn edges. Spores subglobose, smooth, orange-yellow, 15–25 μ.

II. Uredinia orange-red, linear, but often confluent, forming very long lines on the stems and sheaths, pulverulent. Spores elliptical, ovate, or pyriform, with four very marked, nearly equatorial germ pores, echinulate, orange-yellow, 25–38 x 15–20 μ.

III. Telial persistent, naked, linear, generally forming lines on the sheaths and stems, often confluent. Spores fusiform or clavate, constricted in the middle, generally attenuated below, apex much thickened (9–10 μ), rounded or pointed, smooth, chestnut-brown, 35–65 x 15–20 μ. Pedicels long, persistent, yellowish-brown.

O and I on Berberis and Mahonia.

II and III on Avena, Hordeum, Secale, Triticum and nearly fifty other grasses. Of great importance on wheat in the Great Plains and along the Ohio.

This fungus was the subject of the classic researches of de Bary [166] begun in 1865 and has since repeatedly served as the basis of fundamental investigations in parasitism, cytology and biologic specialization. That the barberry æciospores can bring about cereal infection seems to have been shown as early as 1816. [176] Inoculations in the reverse order were made in 1865. [166] Extensive studies by Eriksson [174] are interpreted by him to show that what was formerly regarded as one species must be separated on biologic grounds into several races which he finally erects as species, though others do not agree that their rank should be specific. These are: P. graminis secalis. P. graminis avenæ. P. graminis tritici. P. graminis airæ. P. graminis poæ. P. phlei-pratensis.

These words from Butler and Hayman [250] show the complexity of the status of these biologic forms.

"Of late years it has become more and more established that parasitic fungi, which are capable like these rusts of living on several hosts, tend to develop 'races' on their different host-species, marked off from each other by definite characters. Sometimes the characters are such as are capable of being detected microscopically. Usually, however, the fungi are, to all appearance, identical, and differences only appear when their manner of

life is carefully studied. The chief of these is the incapacity of a race to attack the host-plants of another race. Such forms as are thus outwardly identical but which show a constant difference in their mode of life are known as "biological" species or as *formæ speciales*.

"A specialized form is considered to be 'sharply fixed' or 'not sharply fixed' according as it is wholly incapable, or sometimes capable, of attacking the host-plants of the other specialized forms of the same fungus. Thus the *P. graminis* of wheat (*P. graminis f. sp. Tritici*) is not sharply fixed, for it can attack barley, rye, &c., sometimes. The *P. graminis* found on grasses of the genus *Agrostis* (*P. graminis f. sp. Agrostis*) is sharply fixed, for it attacks this genus only and does not pass to the other grasses on which it has been tried.

"But even the not sharply fixed forms, such as the *P. graminis* of wheat, may be entirely incapable of attacking some of the species which bear other forms of the same fungus. In other words a form may be not sharply fixed in regard to some host-plants and sharply fixed in regard to others. A striking instance of this occurs in India. *P. graminis* can be divided amongst others into races on wheat (*f. sp. Tritici*), rye and barley (*f. sp. Secalis*), and oats (*f. sp. Avenæ*). The *f. sp. Tritici* can attack barley sometimes, and did so in four out of sixteen of our inoculations, but it does not, in India at least, attack oats. Hence it is sharply fixed in regard to oats and not sharply fixed in regard to barley. The *f. sp. Secalis* on barley also does not pass to oats, but infected wheat doubtfully in two out of sixteen inoculations. These two forms are common in India, and the practical bearing of their not passing to oats is considerable, for the *f. sp. Avenæ* has not yet been observed in this country."

The mycelium branches intercellularly and bears small haustoria which penetrate the cells. In the barberry it is local. The epiphyllous pycnia appear first followed soon by the mainly hypophyllous æcia. The flask-shaped pycnia at maturity bear numerous pycniospores and exserted paraphyses. Their hyphæ are orange-tinted, due to a coloring matter in the protoplasm or later in the cell walls.

The æcium originates in the lower region of the mesophyll

from a hyphal weft. The fertile branches give rise to chains of spores every alternate cell of which atrophies. The outer row of sporophores and potential spores remains sterile to form the peridium. When young the æcium is immersed and globular, at maturity erumpent and forms an open cup. These spores germinate by a tube capable upon proper hosts of stomatal infection and following this of producing the uredinium.

Urediniospores are produced throughout the season even through the winter under proper climatic conditions. They also remain viable for weeks [166, 174] and doubtless serve hibernation purposes. [306]

Teliospores arise later in the season in the uredinia or in separate telia. Unicellular teliospores, mesospores, are occasionally seen. Teliospores germinate best after normal outdoor hibernation, producing the typical 4-celled promycelium, long sterigmata and solitary basidiospores. If under water the usual promycelium becomes abnormal and resembles a germ tube.[167, 175]

The æcial stage may not occur under certain climatic conditions, and the uredinia alone perpetuate the fungus.[251, 252, 253, 306] It therefore follows that eradication of the barberry as was attempted by legislative enactment in 1660 in Europe and in 1728 and 1755 in Connecticut and Massachusetts [255] does not exterminate the rust [254] (see also [306, 29]).

Basidiospores were shown by De Bary, [166] confirmed by Ward [256] and Eriksson, to be incapable of infecting wheat leaves. Sufficient such attempts have, however, not been made on young tissue. [170]

Jaczewski [258] succeeded in securing germination of pycniospores but the resulting mycelium soon died and infection was not attained. The same author holds that æciospores may remain viable about a month, the urediniospores a much shorter time. Still hibernation by urediniospores is possible where climatic relations allow the formation of new uredinia during the winter.

P. rubigo-vera (D. C.) Wint.[169, 171, 259, 306]

I (=Æ. asperifolium, Pers). Spots large, generally circular, discolored, generally crowded. Peridia flat, broad, with torn white edges. Spores subglobose, verrucose, orange-yellow, 20–25 μ.

II. Uredinia oblong or linear, scattered, yellow, pulverulent.

Spores mostly round or ovate, echinulate, with three or four germ pores, yellow, 20–30 x 17–24 μ.

III. Telia small, oval, or linear, black, covered by epidermis, surrounded by a thick bed of brown paraphyses. Spores oblong or elongate, cuneiform, slightly constricted, the lower cell generally attenuated, apex thickened, truncate or often obliquely conical. Spores smooth, brown, variable in size, 40–60 x 15–20 μ. Pedicels short.

Heterœcious; O and I on Boraginaceæ.

II and III on rye. The teliospores germinate as soon as mature.

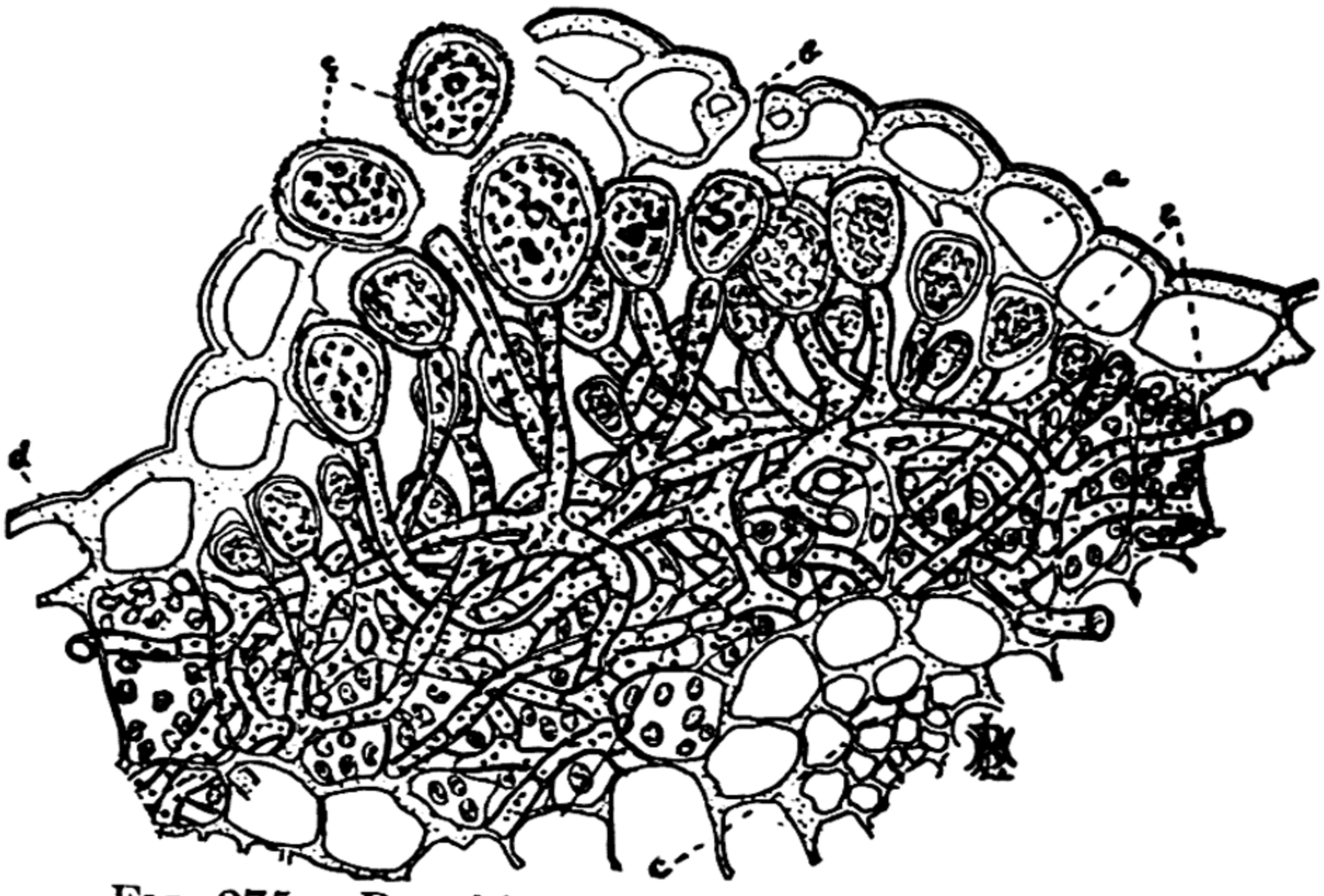


FIG. 275.—P. rubigo-vera, section of uredinium. After Bolley.

P. triticina Erik. is the most common and widely distributed of all rusts of the United States and is a serious wheat pest in India.[250] It ordinarily shows only the uredinial stage. The teliospores germinate the following spring after a resting period.

Coextensive with wheat culture.[306] Epidemics are frequent.

Bolley [6, 7, 11] (see also [306]) has shown it capable of hibernation by urediniospores and by live winter mycelium and it has further been shown that the spores themselves can survive freezing in ice. The æcial stage can be entirely omitted.

This species is combined with P. triticina by Carleton [171] and treated as two races. The name P. dispersa is also used to cover the same two species. P. rubigo-vera tritici on wheat and P. rubigo-vera secalis on rye.

The æcial stage of the former of these is not known. Its uredinia survive the severest winters even so far north as the Dakotas.

P. coronata Cda.[169, 248, 306]

I (=Æ. rhamni). Peridia often on very large orange swellings, causing great distortions on the leaves and peduncles, cylindrical, with whitish torn edges. Spores subglobose, very finely verrucose, orange-yellow, 15–25 x 12–18 μ.

II. Uredinia orange, pulverulent, elongated or linear, often confluent. Spores globose or ovate, with three or four germ pores, echinulate, orange-yellow, 20–28 x 15–20 μ.

III. Telia persistent, black, linear, often confluent, long covered by the epidermis. Spores subcylindrical or cuneiform, attenuated below, constriction slight or absent, apex truncate,



Fig. 276.—P. coronata, various teliospore forms. After Bolley.

somewhat thickened, with six or seven curved blunt processes, brown, 40–60 x 12–20 μ. Pedicels short, thick.

Heterœcious; I, on Rhamnus frangula.

II and III on various grasses but not on oats.

From this form as earlier understood Klebahn has separated **P. coronifera** Kleb. on evidence derived from inoculations, and made the latter to include these forms with the æcial stage on Rhamnus cathartica and the uredinial and telial stages on Avena, Lolium, Festuca, Holchus, Alopecurus and Glyceria. P. coronifera has been still further divided by Eriksson into eight biologic forms and P. coronata into three such forms.[307]

P. glumarum (Schm.) Er. & Hu.[248, 250] is widely distributed on wheat, rye, barley and a few other grasses in India and Europe but is not known in America.[306] Its æcia are not known. By some this is regarded as a race of P. rubigo-vera. Both uredinia and teliospores have been reported in the pericarp of grains.[16]

P. simplex (Korn.) Er. & He.

I. Unknown.

II and III on barley in Europe and seemingly of recent introduction into the United States.[306]

One of the least important of the grain rusts. Mesospores are common.

P. sorghi Schw.[260]

I (=Æ. oxalidis). Peridia hypophyllous, rarely amphigenous, crowded, concentric, epispore smooth, 24–28 μ.

II. Uredinia amphigenous, numerous, often confluent; spores globose to ovate, 23–30 x 22–26 mm., slightly verrucose.

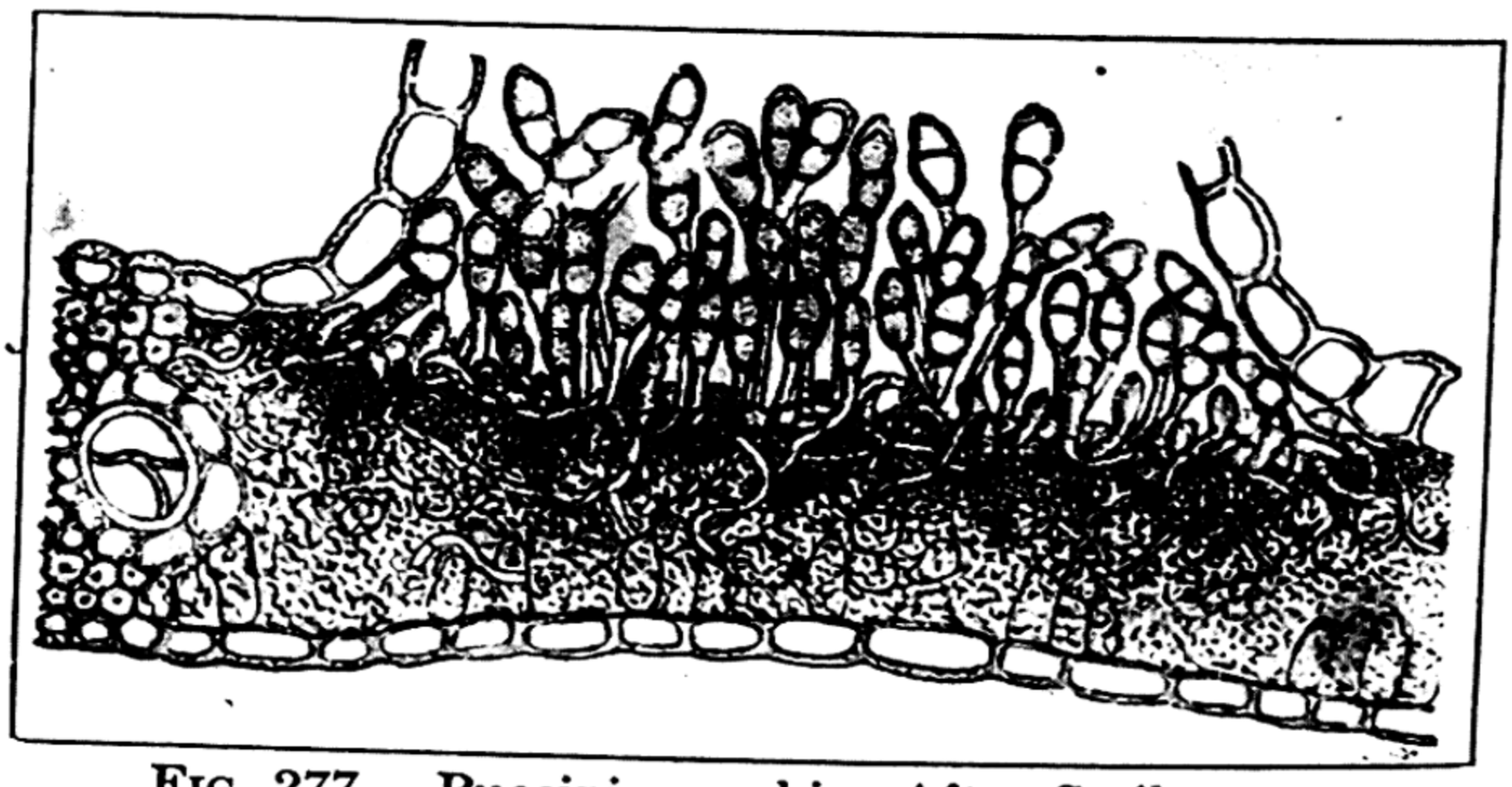


FIG. 277.—Puccinia sorghi. After Scribner.

III. Telia amphigenous, black. Spores ovate-oblong or clavate-obtuse, constricted. Epispore thick, 28–45 x 12–17 μ, smooth, pedicel long, 5 μ, persistent.

Heterœcious. O and I on Oxalis. II and III on Zea. Of little economic importance.

The relation of the æcial stage was demonstrated by Arthur;[260] it is believed, however, that hibernation is largely by the urediniospores.[5]

P. purpurea C. Amphigenous, spot purplish, sori irregular, dark-brown.

II. Urediniospores ovate, 35 x 25–30 μ, smooth, brown.

III. Teliospores elongate, ovate, brown, long-pedicellate, 40–45 x 22–25 μ. On Sorghum in Southern United States and West Indies.

P. phlei-pratensis E. & H.[348-261, 303-305]

I. Æcia probably on Berberis, but rarely formed.

II. Uredinia 1–2 mm. long on leaves and stems, confluent in lines 10 mm. or more long, yellow-brown; spores oblong, pyriform, spiny, 18–27 x 15–19 μ. Mycelium perennial.

III. Telia in leaves, sheaths and stems, 2–5 mm. long or more, confluent, narrow, dark-brown to black, open or partly

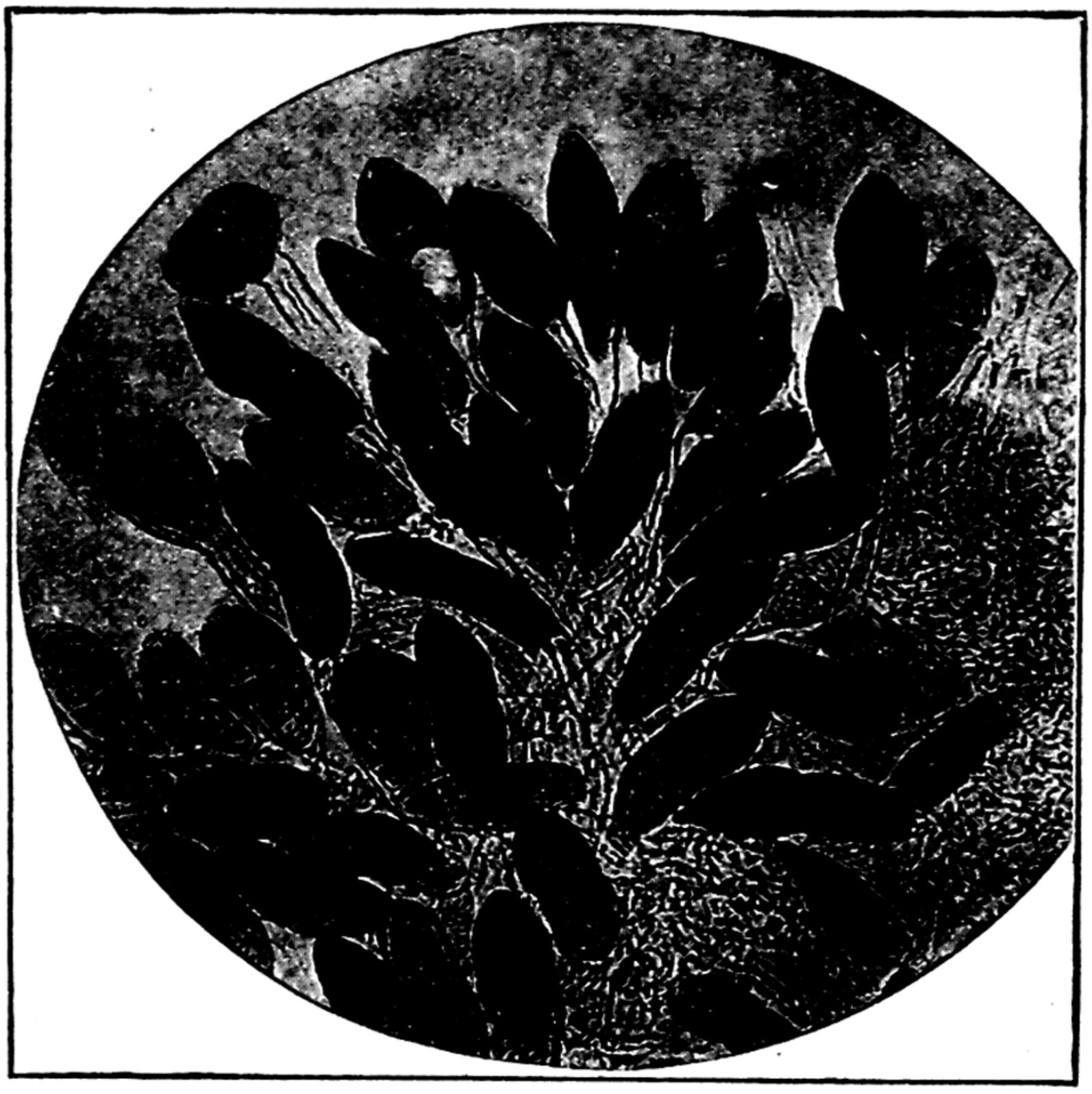


FIG. 278.—P. malvacearum. After Holway.

closed. Spores fusiform or club-shaped, medially constricted, chestnut-brown, apically thickened, 38–42 x 14–16 μ.

II and III on timothy grass.

This species is closely related to P. graminis and probably a derivate from it, but it does not seem capable of infecting the barberry under ordinary conditions.[261, 248]

Inoculation experiments with timothy rust at Washington, D. C., show that it can be transferred easily to various grasses. Similar results have been obtained by Eriksson in Europe. It is not a well fixed species and by using bridging hosts it can be made to

transfer to various cereals which it will not attack directly. That such transfers take place in nature to some extent is probable.[303]

P. poarum Niess occurs on bluegrass.

P. malvacearum Mont.[262–265]

III. Telia grayish-brown, compact, round, pulvinate, elongate on the stems, scattered, seldom confluent, pale reddish-brown. Spores fusiform, attenuated at both extremities, apex sometimes rounded, constriction slight or absent, apical thickening slight, smooth, yellow-brown, 35–75 x 15–25 μ. Pedicels firm, long, sometimes measuring 120 μ.

A lepto-puccinia on three species of Althea, seven of Malva, two of Malope; particularly serious on the hollyhock. A native of Chili, it was first known as a pest in Australia; soon afterward in Europe. It seems to have entered the United States sometime prior to 1886 and is now almost universal. The teliospores germinate immediately in suitable environment, mainly from the apical cell, or may remain alive over winter and originate the spring infection. The mycelium also hibernates in young leaves. Mesospores are common. 3 to 4-celled teliospores are also met.



FIG. 279.—P. helianthi, uredinio- and teliospores. After Cobb.

P. heterogena Lag. is also described on hollyhock from[302] South America.

P. chrysanthemi Roze.[266–268]

II. Uredinia chocolate-brown, single or in circular groups, hypophyllous, rarely epiphyllous. Spores spherical to pyriform. Membrane spiny and with three germ pores, 17–27 x 24–32 μ.

III. Telia dark-brown hypophyllous. Teliospores rarely in uredinia, dark, obtuse, apex thickened, membrane thick, finely spiny, 20–25 x 35–43 μ. Pedicel 1–1½ times the spore length.

On cultivated Chrysanthemum. Occasionally urediniospores like the other urediniospores in all other respects but 2-celled are found; a habit unique with this rust. In many places urediniospores may be produced continuously and teliospores be but rarely seen, thus in America only urediniospores have been found. It was

first seen in America in 1896 (Mass.) and soon spread over the country. Numerous inoculation trials go to show that it is independent of the other rusts common on nearly related Compositæ.[266]

P. arenariæ Wint.[301]

III. Telia compact, pulvinate, roundish, scattered, often circinate. Spores broadly fusiform or pyriform, summits pointed or rounded, often thickened, base rounded or attenuated, slightly constricted, smooth, pale yellowish-brown, 30–50 x 10–20 μ. Pedicels hyaline, colorless, as long as the spores.

A lepto-puccinia common on Dianthus.

P. helianthi Schw.

O. Pycnia clustered.

I. Æcia in orbicular spots; peridial margins pale, torn; spores orange, rarely whitish.

II. Uredinia minute, round, chestnut-brown, spores globose to ovate, 22–26 x 17–22 μ, minutely spiny.

III. Telia round, dark-brown to black; spores rounded at base, slightly constricted, 38–50 x 20–27 μ, smooth; pedicel hyaline, equal to or longer than the spores.

Autœcious on numerous species of Helianthus, probably divisible into numerous biologic forms. Imported from America to Europe.

Arthur [309] used fifteen species of Helianthus on which to sow the teliospores of Puccinia helianthi produced on three species. The results are given in table I on page 388.

In the course of three years' work with this species sixty sowings were made.

"Looking over the table it will be seen that each set of spores grew upon the species of host from which derived, but not upon the other two species, except that spores from *H. lætiflorus* sown on *H. mollis* gave a tardy showing of pycnia, without further development. Also each set of spores grew luxuriantly upon *H. annuus*, and each made a feeble growth upon *H. tomentosus*, but on all other species they either failed to infect or made a feeble growth, with the single exception that spores from *H. lætiflorus* grew well on *H. scaberrimus*." *P. Helianthi* thus affords an example of a single species having many races, for which *H. annuus* acts as a bridging host.

TABLE I

RESULTS OF INOCULATIONS OF HELIANTHUS RUST *

	Teliospores taken from		
	H. mollis	H. grosse-serratus	H. lætiflorus
1. H. annuus	+	+	+
2. H. decapetalus	a	o	a
3. H. divaricatus	a	a	—
4. H. grosse-serratus	o	+	o
5. H. hirsutus	—	o	o
6. H. kellermani	o	a	—
7. H. lætiflorus	o	o	+
8. H. maximiliani	o	o	a
9. H. mollis	+	o	—
10. H. occidentalis	—	o	—
11. H. orgyalis	o	o	o
12. H. scaberrimus	o	o	+
13. H. strumosus	—	o	o
14. H. tomentosus	—	—	—
15. H. tuberosus	o	o	o

+ Abundant infection. — Infection, but slow growth and few or no æcia formed. o No infection. a Not sown.

P. violæ (Schum) D. C.[269]

I. Æcia on the leaves in circular concave patches, often causing much distortion on the stems, flat with white torn edges. Spores subglobose, finely verrucose, orange-yellow, 16–24 x 10–18 μ.

II. Uredinia brown, small, roundish, scattered, soon naked. Spores roundish or elliptical, brown, echinulate, 20–26 μ in diameter.

III. Telia black, roundish, small, pulverulent. Spores elliptical or oblong, slightly attenuated at the base, with an apical thickening, constriction almost absent, brown, 20–35 x 15–20 μ. Pedicels long, deciduous.

An autœcious eu-type on many species of Viola, throughout the world. Of little economic import.

P. convallariæ-digraphidis (Soph.) Kleb. is heterœcious;

I on Convallaria majalis. III on Phalaris.

* Adapted from Arthur.

P. gentianæ Strauss is a eu-puccinia on many species of cultivated gentians. **P. gladioli** Cast occurs on gladiolus. **P. granularis** Kalc. & Cke. is on cultivated Pelargoniums in France;[270] **P. tulipæ** Schr. on tulips; **P. scillæ** Lk. on Scilla; **P. schroeteri** Pass. on Narcissus in Europe. **P. pazschkei** Diet. is a lepto-puccinia on cultivated saxifrages in Europe. **P. horiana** Hen.

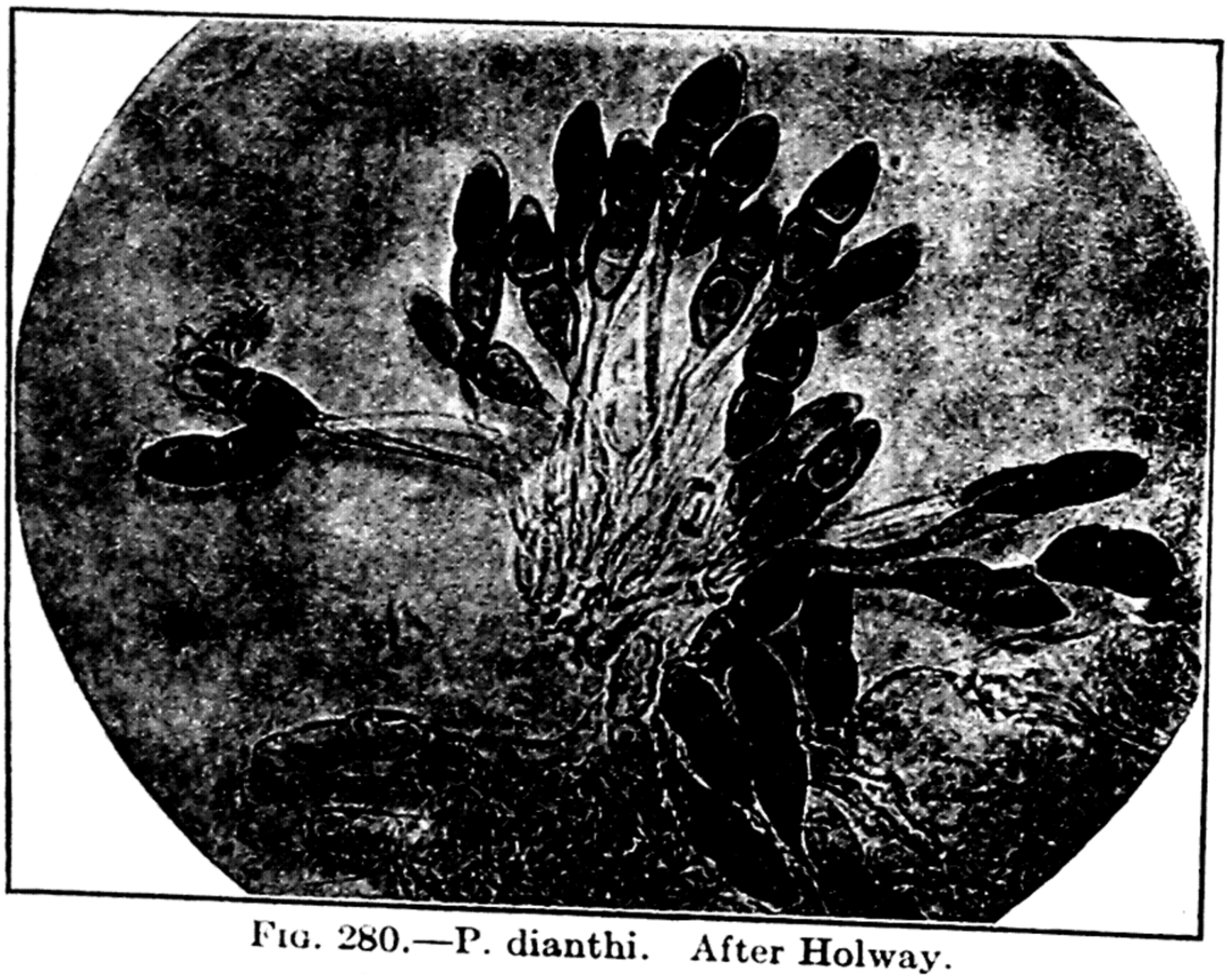


FIG. 280.—P. dianthi. After Holway.

is destructive on Chrysanthemums in Japan.[271] **P. iridis** (D. C.) Duby, a hemi-puccinia, is found on many species of Iris. **P. cannæ** Hen. in its uredinial stage is destructive to Cannas in the West Indies. **P. persistens** Plow, is heterœcious. I on Thalictrum. II and III on Agropyron. **P. asteris** Duby. is a very common lepto-puccinia on various asters. **P. anemones-virginianæ** Schw. is a lepto-puccinia common on anemone.

KEY TO **Uredinales Imperfecti** (p. 335)

Spores catenulate	
Peridium absent	1. **Cæoma,** p. 390.
Peridium present	
Toothed, body cup-shaped	2. **Æcidium,** p. 390.
Fimbriate, body elongate	3. **Rœstelia,** p. 391.
Irregularly split	4. **Peridermium,** p. 390.
Spores not catenulate	5. **Uredo,** p. 392.

Æcidium Persoon (p. 389)

Spores surrounded by a cup-shaped peridium; produced catenulate in basipetal series. Germination as in Uredo.

The species are very numerous and belong in the main to Puccinia and Uromyces. Most of the forms of economic interest are found under these genera. A few others of occasional economic bearing whose telial stage has not yet been recognized are given below.

A. brassicæ Mont. on Brassica is perhaps identical with Puccinia isiacæ. See p. 378. **A. tuberculatum** E. & K.[211] is reported as destructive on the poppy mallow. **A. pelargonii** Thüm. occurs on geraniums;[270] **A. otogense** Lindsay on Clematis.[277] **A. cinnamomi** Rac. is serious on the cinnamon tree in Java.

Cæoma Link (p. 389)

Sori without a peridium, accompanied by pycnia, with or without paraphyses, produced in chains. Germination as in Uredo.

The forms are mostly stages of Melampsora, Phragmidium or their kin. Those of economic interest are found under Gymnoconia and Melampsora.

Peridermium Léveillé (p. 389)

Pycnia truncate-conic.

Peridia caulicolous or foliicolous, erumpent, saccate to tubular, lacerate-dehiscent, spores catenulate or at maturity appearing solitary, globose to elliptic or oblong, polyhedral by pressure, yellowish-brown. Epispore always verrucose-reticulate.

The æcial stages of Coleosporium, Cronartium, Pucciniastrum, Melampsorella and Chrysomyxa.

The peridia usually extend conspicuously above the host surface, and rupture irregularly by weathering.

All of the species grow on the Coniferæ, most of them on Pinus on both leaves, branches and bark. On the leaves the æcia are much of the type shown in Fig. 256. When on the woody parts great distortion may be caused by the perennial fungus and much injury result to the wood (see Cronartium quercus, p. 352).

The mycelium may live intercellularly in rind, bast and wood

of pine and continues to extend for years causing swellings of twigs. Pycnia are either subcuticular or subepidermal and the pycniospores often issue in a sweetish liquid. Æcia occur as wrinkled sacs emerging from the bark of the swollen places and bear spores perennially.

A key to some thirty species is given by Arthur & Kern.[195]

So far as it relates to the distribution of the Peridermiums to their telial genera it is as follows:

KEY TO SPECIES OF **Peridermium**

Pycnia subcuticular	
Æcia cylindrical	**Pucciniastrum.**
Æcia tongue-shaped	**Melampsorella, Melampsoridium.**
Pycnia subepidermal	
Æcial peridia one cell thick	
On Pinus	**Coleosporium.**
On Picea	**Melampsoropsis.**
On Abies	**Uredinopsis.**
Pycnia subcorticular	
Æcial peridia more than one cell thick	**Cronartium.**

Such forms as are of economic interest and of which the telial stage is known are discussed under Coleosporium, Cronartium, Melampsorella, Melampsoropsis and Pucciniastrum.

Several other forms are found on pine, spruce and Tsuga.

Rœstelia Rebentisch (p. 389)

O. Pycnia spherical or cup-formed.

I. Æcia with strongly developed thick-walled peridium, flask-shaped or cylindric; spores globose, 1-celled, brown to yellow, catenulate, with several evident germ pores.

FIG. 281.—R. pyrata, cups showing peridial cells. After King.

The forms are the æcial stages of Gymnosporangiums and occur mostly on Rosaceous hosts. The economic forms will be found under Gymnosporangium.

Uredo Persoon (p. 389)

Spores produced singly on the terminal ends of mycelial hyphæ. Germination by a germ-tube which does not produce basidiospores, but enters the host-plant through the stomata.

These forms are in the main discussed under their telial genera.

U. orchidis Wint. and **U. satyrii** Mass. are in the leaves of cultivated orchids. **U. tropæoli** Desm. is found on Tropæolum; **U. arachidis** Lag. the peanut;[325] **U. aurantiaca** Mont. on Oncidium.[280] **U. autumnalis** Diet. on Chrysanthemums in Japan[281] and **U. kuhnii** (Kr.) Nak. on sugar cane in Java.

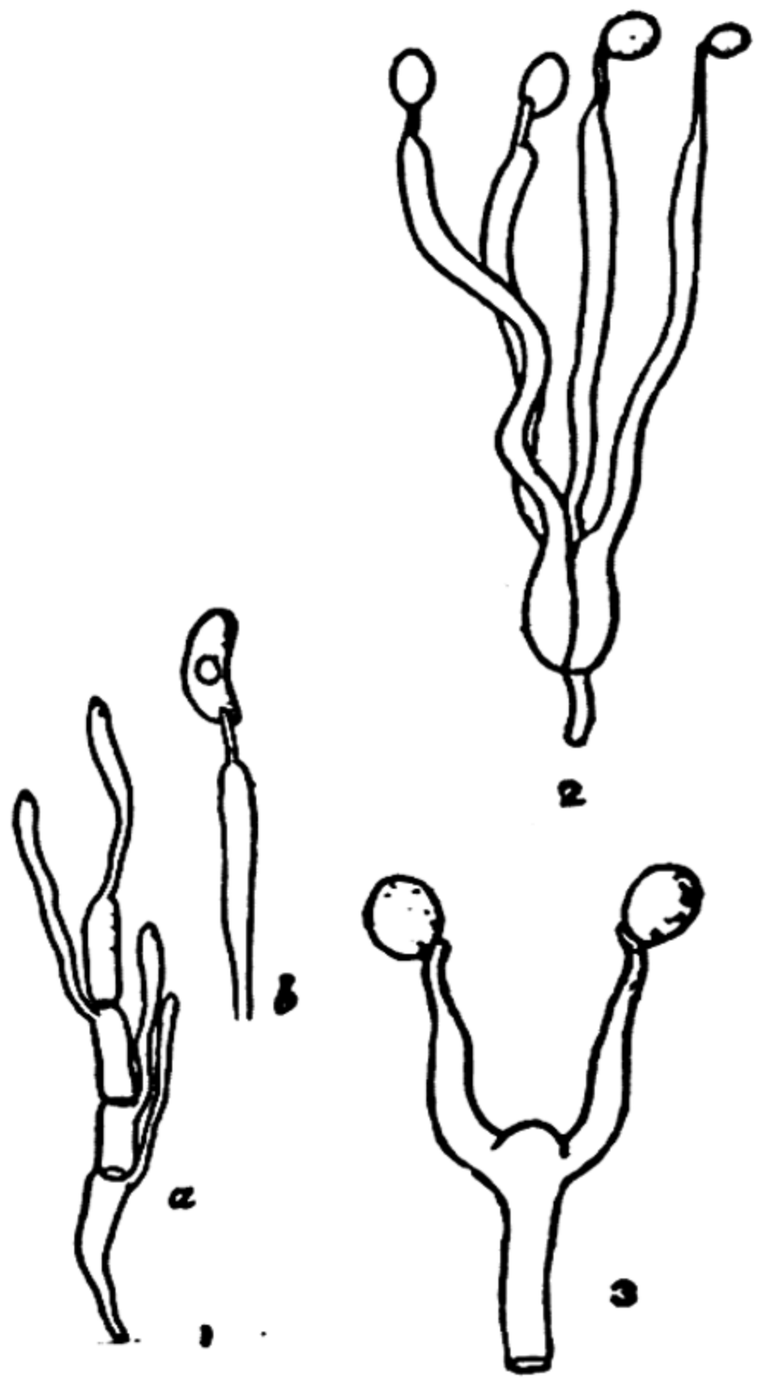


FIG. 282.—Various basidia of the lower basidiomycetes, 1, auriculariaas; 2, tremellas with longitudinal divisions; 3, dacryomycetes with undivided forked basidium.

The **Auriculariales** (p. 323)

Mycelium septate, forming a gelatinous, irregular and expanded or capitate sporocarp; hymenium variable, densely beset with basidia, on each segment of which is borne a long sterigma, with its single spore.

The Auriculariales are mostly saprophytic and of little economic importance. They embrace some fifty species in two families and are chiefly of interest on account of the form of their basidia Fig. 282, which shows relationship both to the Ustilaginales and to the orders to follow.

KEY TO FAMILIES OF **Auriculariales**

Hymenium gymnocarpous. . . . . 1. **Auriculariaceæ**, p. 392.
Hymenium angiocarpous. . . . . 2. **Pilacraceæ**.

Auriculariaceæ

KEY TO TRIBES OR GENERA OF **Auriculariaceæ**

Sporocarp arising from a ton-like base of mycelial threads. . . . . I. **Stypinelleæ**.

Basidia free on the end of the hyphæ without saccate cell.....	1. **Stypinella,** p. 393.
Basidia subtended by a saccate cell.	2. **Saccoblastia.**
Sporocarps crustaceous.....	II. **Platyglœeæ.**
Sporocarps gelatinous, auriform or cap-shaped.	III. **Auricularieæ,** p. 393.

In tribe III, Auricularieæ, there is a single genus, Auricularia. Cap more or less cup-shaped or ear-like, jelly-like but firm when wet, horny when dry, the hymenium often veined or folded, but without teeth. The name refers to the cup-like form.

A. auricula-judiæ (L.) Schr. is a very common saprophyte which is occasionally parasitic on elder, elm, and mulberry in Europe.

In tribe I, few cases of parasitism of any importance are reported.

Stypinella mompa (Tan.) Lin. is found on the roots of mulberry in Japan.[19]

Eubasidii (p. 299)

The Eubasidii represent the higher development of the basidia-fungi and contain the majority of the species. The basidia, the typical club-shaped undivided stalks, bear usually four, sometimes two, six, or eight unicellular spores on a like number of sterigmata and are mostly arranged in **hymenia.** There is great diversity in the form and size of the sporophore from an almost unorganized mycelial microscopic weft to the large complex structures of the toad stools and puff balls. Conidia and chlamydospores while occasionally present are much less common than in the preceding groups or orders.

The cells of the sporophore in many forms investigated are binucleate;[33] in other forms they are multinucleate.

The origin of the binucleate condition often antedates the formation of the sporophore and may occur far back in the mycelium, perhaps as far back as the germinating basidiospore itself.[34, 35, 36] In the basidial layer, however, even of those forms with multinucleate vegetative cells, the nuclei are reduced to two so that the general statement is permissible that in the hymenial layer of the Basidiomycetes the cells are binucleate. From such cells two nuclei wander into the basidium primordium where they fuse to one, reducing this cell to a uninucleate condition. This

nucleus by two mitoses gives rise to four nuclei which wander through the sterigmata into the spores and constitute the four basidiospore nuclei.

The significance of this phenomenon of fusion in the basidium followed by division, which is wide spread and apparently the

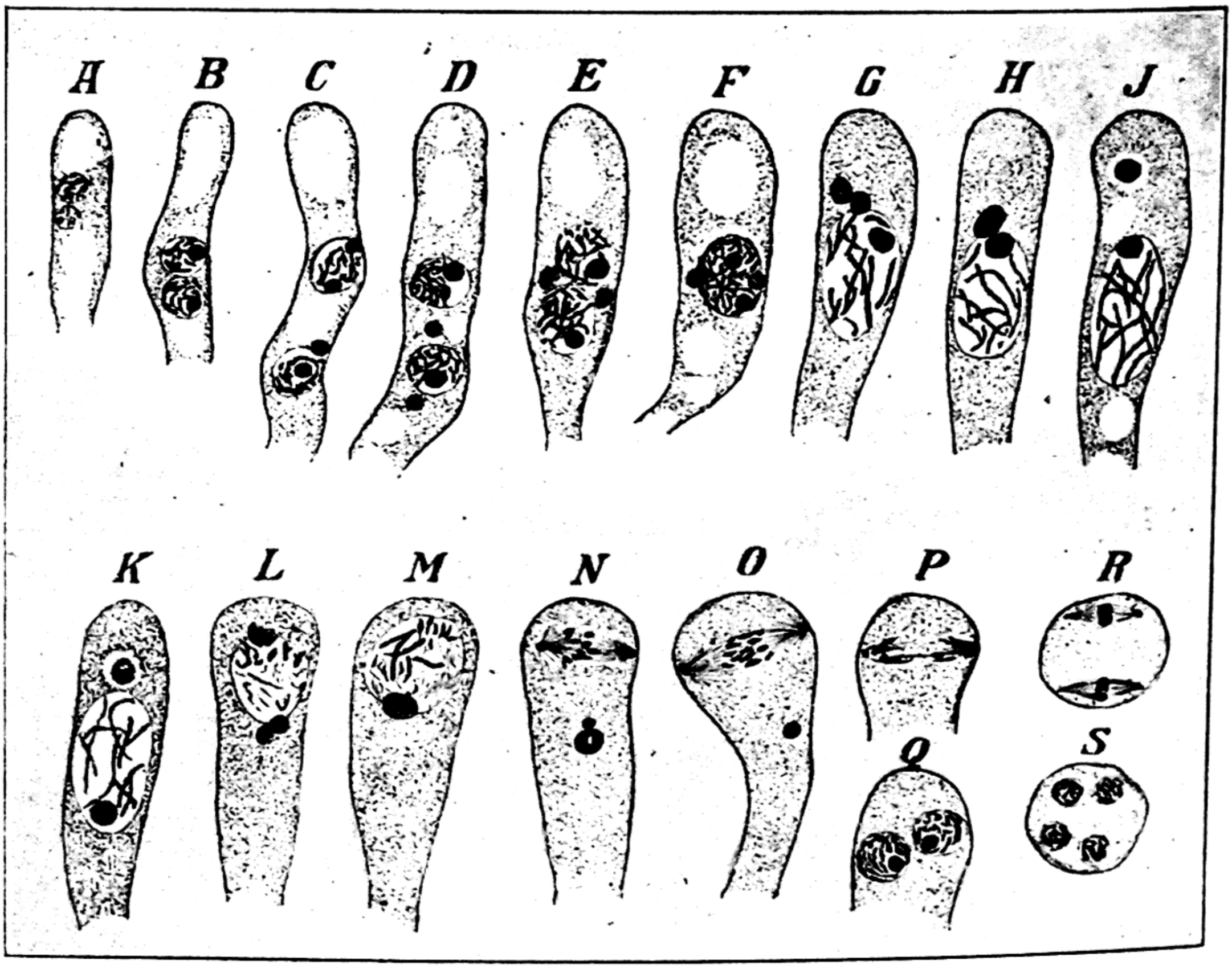


Fig. 283.—Stages in the development of the basidium (Agaricus); original binucleate condition, followed (E–F) by fusion, and subsequent mitosis N–R, resulting in four spore nuclei. After Wager.

dominant typical phenomenon among the Basidiomycetes including both high forms, Agarics,[37] and low forms, Dacryomycetes,[38] the Uredinales [178, 180, 189, 313, 315] and even the Gasteromycetes (Maire),[319] is much debated. By some it is regarded as a very much modified type of fertilization, a view to which support is lent by the fact that in some of these fungi, perhaps all, the nuclei multiply by a process of conjugate division. Thus the two nuclei found in the young basidium, although belonging to the same cell may in ancestry be very distantly related.

Key to Orders of Eubasidii

Gelatinous fungi with forked basidia. ..... 1. **Dacryomycetales.**

Basidia clavate, undivided

Hymenium without stroma, parasites, basidia free, strict ..... 2. **Exobasidiales,** p. 396.

Stroma usually well developed, fleshy, coriaceous, leathery or woody

Spores arising from basidia which form a distinct membranous hymenium which is naked at maturity, and frequently covers the surface of gills, pores or spines (Hymenomycetes). ..... 3. **Agaricales,** p. 398.

Spores arising from basidia enclosed in a definite peridium (Gasteromycetes.)

Spores borne in a more or less deliquescent gleba which is at first enclosed in a peridium, but is at maturity elevated on stipe..... 4. **Phallales,** p. 462.

Spores remaining within the peridium until maturity

Basidia united into a hymenium which lines the walls of irregular cavities

Hymenial cavities remaining together in the peridium, their boundaries mostly disappearing at maturity

Fleshy until the maturity of the spores, capillitium none. ..... 5. **Hymenogastrales.**

Fleshy when young, at maturity filled with dust-like spore-masses mixed with capillitium (puff balls) .. 6. **Lycoperdales,** p. 464.

Hymenial cavities separating at maturity from the cup-like peridium (bird-nest fungi). 7. **Nidulariales.**

Basidia uniformly distributed through the peridium or forming skein-like masses... 8. **Sclerodermatales.**

The **Dacryomycetales** include forms with a gelatinous sporophore. They are mostly small, inconspicuous saprophytes, common on decaying wood, leaves, etc. The **Hymenogastrales** are puff-ball forms, and are very numerous and of very diverse structure. None have been reported as parasitic. The **Nidulariales** is a small order comprising the curious bird-nest fungi, all saprophytes. The **Sclerodermatales** are thick-skinned puff balls, mostly subterranean, and not known to be parasitic.

Exobasidiales (p. 395)

Strictly parasitic, the mycelium penetrating the host and usually causing marked hypertrophy; hymenium unaccompanied by fleshy sporocarp, consisting only of the closely-crowded, clavate basidia which break through the epidermis of the host.

The basidia bear four, rarely five or six sterigmata and spores. The spores are mostly curved. Conidia are also found in some species. The basidiospores germinate with a germ tube which produces fine sterigmata and secondary spores capable of budding. The hymenial cells are binucleate, the two nuclei of the basidial cell fusing into one basidium-nucleus. This divides mitotically giving rise to the spore nuclei.

This order among the basidia fungi is analogous to the Exoascales among the ascus fungi. There are two genera and some twenty-five species.

Key to Genera of **Exobasidiales.**

Basidia 6-spored; not gall producers..... 1. **Microstroma,** p. 396.
Basidia 4-spored; producing galls..... 2. **Exobasidium,** p. 396.

Microstroma Niessl. contains only three species of which
M. album (Desm.) Sacc. is on oak;
M. juglandis (Ber.) Sacc. on Juglans and Hicoria.

Exobasidium Woronin

Mycelium penetrating the host and causing distinct hypertrophy, hymenium subcuticular, erumpent, basidia 4-spored, spores elongate.

There are some twenty species, mostly on members of the

Ericaceæ. Cultural work and studies in infection are needed before species can be properly delimited.[39]

E. vaccinii (Fcl.) Wor. occurs on Vaccinium vitis idæa, forming large blisters on the leaves, rarely on petioles and stems, discoloration red or purple. The fungus appears as a white bloom on the under surface of the leaf; spores narrowly fusiform, 5–8 x 1–2 μ.

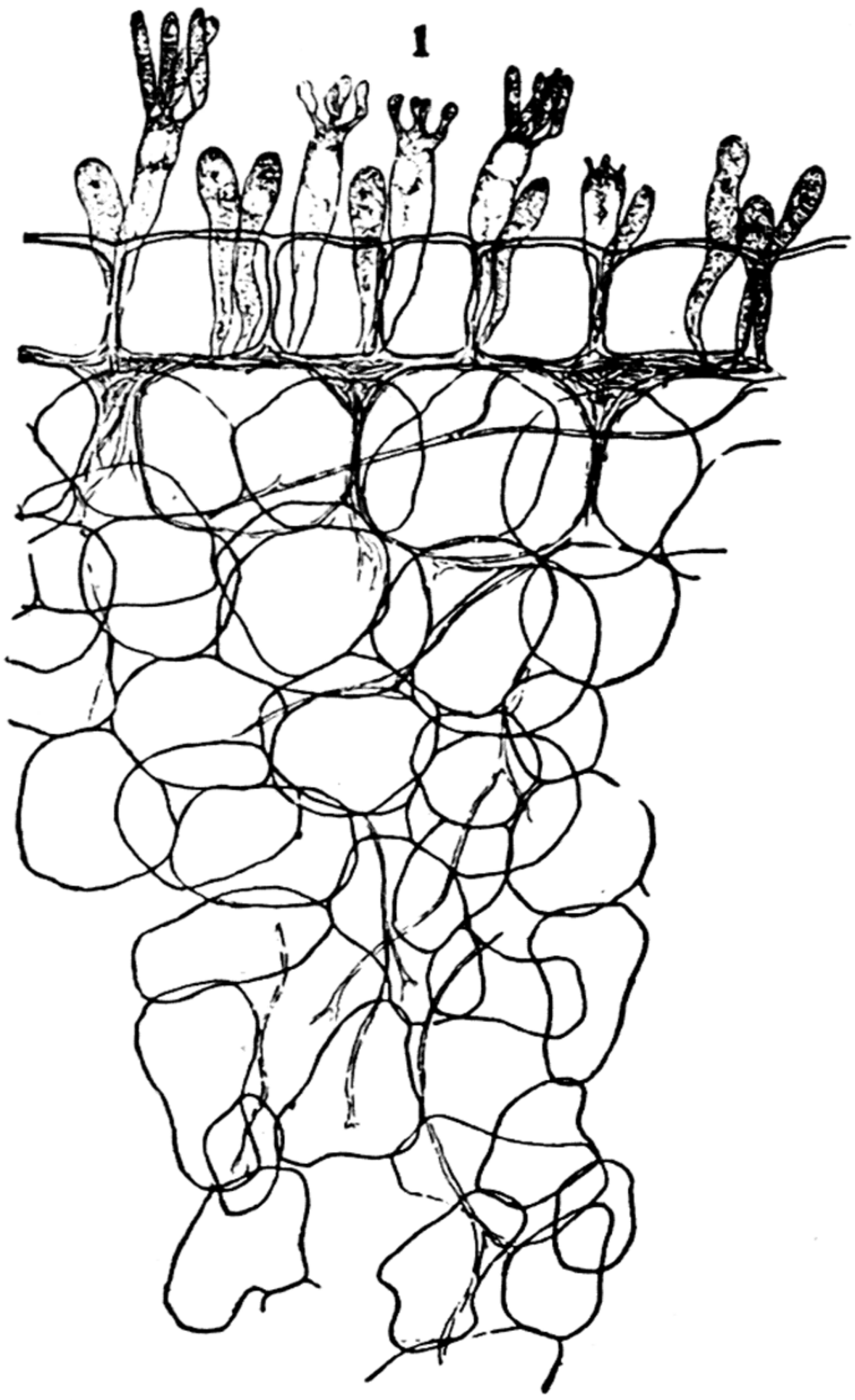


FIG. 284.—Exobasidium andromedæ on Andromeda, showing host cells, mycelium, basidia and spores. After Richards.

Richards [39] who studied E. vaccinii and E. andromedæ from inoculations concludes:

"Aside from the form of the distortion, E. vaccinii and E. andromedæ cannot well be distinguished. The former can produce the same form of distortion on both Gaylussacia and Andromeda and the latter has been made to produce a similar growth on Andromeda. Microscopically these forms do not differ. The natural conclusion is that these two species of Exobasidium are one and the same and the form producing large bag-like distortions on Andromeda should be considered a form of E. vaccinii."

E. oxycocci Rost causes greater hypertrophy than E. vaccinii, distorting young twigs and leaves; spores 14–17 x 30 μ; smaller conidia often present. The mycelium infests the leaves and stems of the cranberry.[40] Morphologically the species agrees closely with E. vaccinii. Infection experiments are needed.

E. vexans Mas [41] causes a serious disease on tea. **E. andromedæ**

Pk., **E. rhododendri** Cram., **E. japonicum shirai** and **E. peckii** Hal. are reported on Rhododendron and Andromeda;

E. azaleæ Pk. and several other species on various Rhododendrons; **E. vitis** Prill. was noted in France on the grape; [42]

E. lauri (Borg) Geyl. is on Laurus.

E. cinnamomi Petch on cinnamon in Ceylon.

Agaricales (p. 395) [1, 2, 13, 14, 48, 50]

This is a very large order of over eleven thousand species. The mycelium grows to long distances over or through the supporting nutrient medium, often forming conspicuous long-lived resistant rhizomorphic strands or sheets, sometimes developing sclerotia or again appearing as a mere floccose weft.

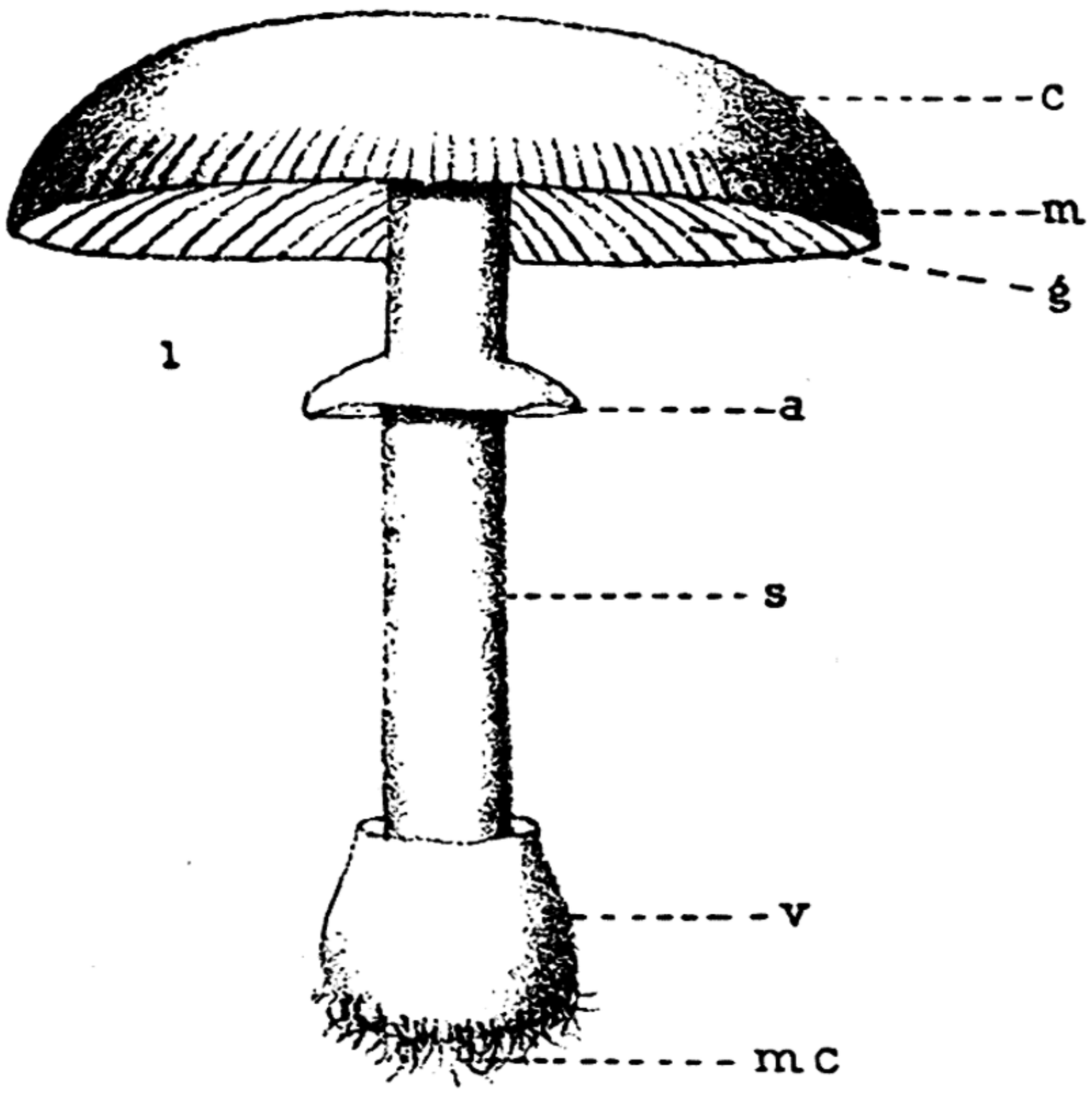


FIG. 285.—An agaric (Amanita) sporophore showing parts; c, pileus; m, c, striated margin; g, gills; a, annulus; s, stem; v, volva; mc, mycelium. After Peck.

The basidia bear four simple spores, in rare cases two, six or eight. Other forms of conidia are found in some species and chlamydospores may be borne either externally on the sporophore, in the hymenium, or inside of the sporophore tissue. In the lowest forms the basidia arise directly from the mycelium without the formation of any definite sporophore but in most species the sporophore is highly complex, consisting of large, stalked or sessile, pseudoparenchymatous structures (toadstools, mushroom, etc.) on special surfaces of which, the hymenium, Fig. 286, lies; covering gills or spines or lining pits or pores.

The general relation of the basidia to the hymenium and the

sporophore is shown in Figs. 285, 286. Families are delimited by the character of the sporophore, distribution of the hymenial surfaces, presence of cystidia, size and color of spores, and other more minor points.

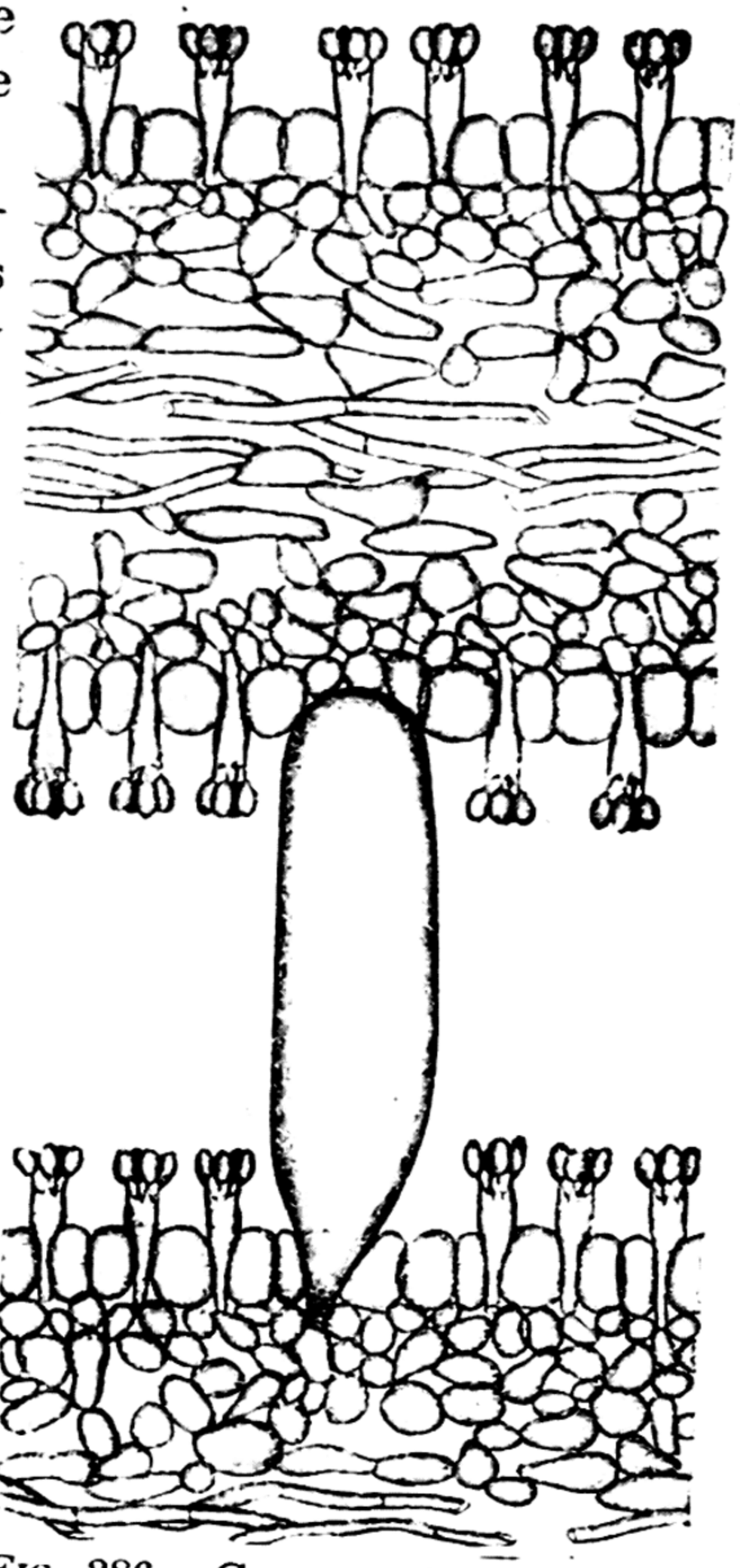


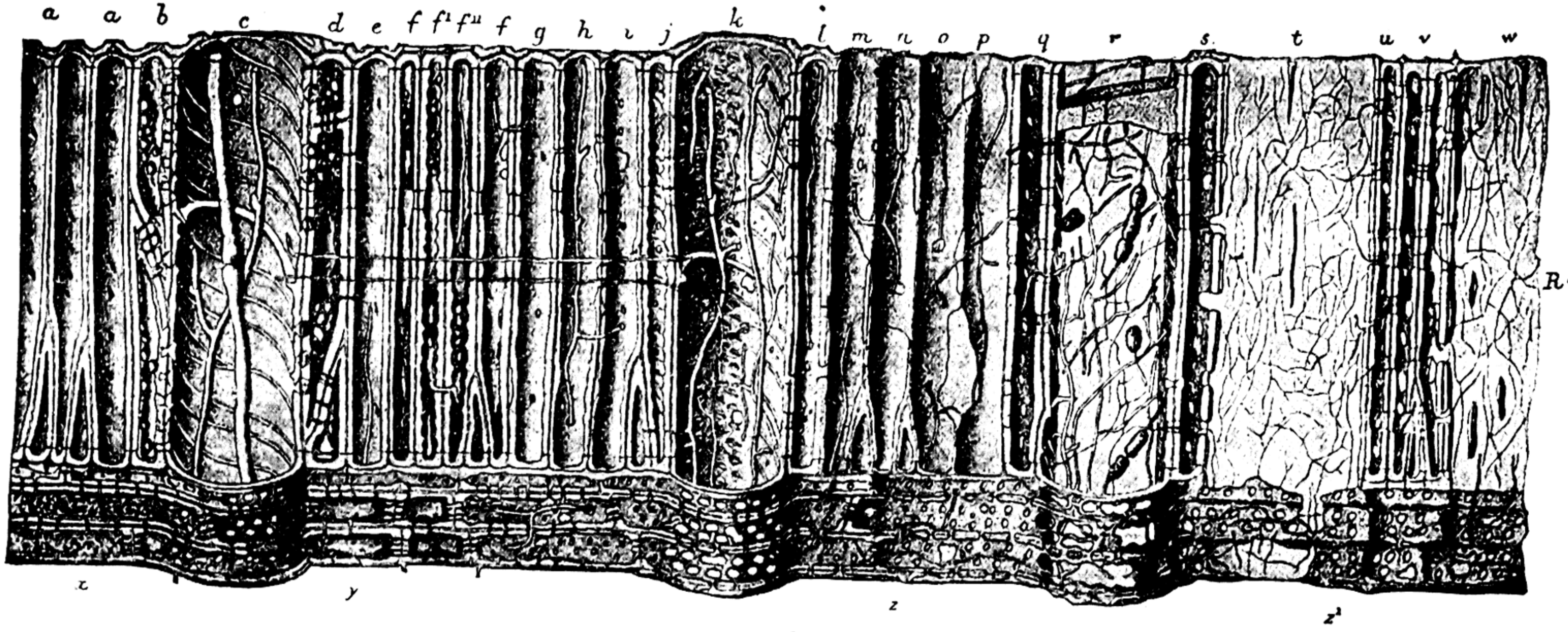
FIG. 286.—Cross section of the gill showing basidia, sterigmata and spores, also a cystidium stretching from one gill to the next. After Buller.

In germination the spore produces a germ tube which develops directly into a mycelium. In many species the young mycelium is conidia-bearing.

Cytologically the group conforms to the general description given on pages 393, 394.

The Agaricales are chiefly of interest to pathologists as wood fungi though in a comparatively few instances they are found on herbs. Upon wood they may do harm. First, as root parasites, in which case death may follow through interference with absorption or anchorage. Second, as causes of heart rots leading to weakness and eventual overthrow of the tree. Third, as parasites of sap wood, cambium or bark leading to death of a part of the host and often its complete loss.

In many instances the fungus draws its subsistence from host cells not actually alive and hence strictly speaking they are saprophytes. Nevertheless, since their ultimate effect upon the tree is to cause disease or death, from the practical viewpoint these fungi are pathogenic. Many species, moreover, can start their career on a host plant as saprophytes and after attaining a stage of vigorous vegetative growth become truly parasitic. In most instances they are **wound parasites**, which cannot gain access to the inner portions of the host through uninjured tissue



25

FIG. 287.—"Radial-longitudinal section; *u*, *v* and *ff* are the autumn wood cells of two successive yearly rings. The mycelium has destroyed the less lignified fibres. In *h* and *i* the secondary thickening has begun to be acted upon. In *m*, *n*, *o* and *p* the secondary thickening has almost disappeared, and the middle lamellae are in process of solution. In the region *t* the fibres have disappeared, leaving a space partly filled with hyphae. The medullary ray cells *x* to *z*, the autumn wood cells *u*, *v*, and the vessel *r*, with its surrounding cells *q* and *s*, *i. e.* the highly lignified elements, are seen to be more persistent.
" The enlargement of the pits of the medullary ray cells may be traced from *x* to *z*.
" Holes made by hyphae through cell-walls are shown in the vessel *k*, also in *f*, *h*, *l*, *n*, and *o*, upon radial walls, while the holes on the tangential walls in the cells *u* and *v* have been made in a similar manner.
" The browning and disappearance of the protoplasm, and the disappearance of starch grains can be traced in the medullary ray from *x* to *y*, and in the wood parenchyma and autumn wood cells from *b* to *g*.
" The largest hyphae having clamped connections are to be seen in the freshly entered vessel *c*. In the vessel *k* the hyphæ are more numerous, the larger ones also with clamp-connections. In the most highly rotten wood, *q* and *w*, the hyphae are much smaller." After Buller.

but must make entrance through some wound, as those due to hail, wind, snow, insects, men and other animals, etc., which exposes the inner bark, cambium, sap wood or heart wood without its natural outer protecting tissues.



FIG. 288. — Tracheid of pine decomposed by Trametes pini. The primary wall dissolved as far as *aa;* in the lower part the secondary and tertiary layers are only of cellulose; *c*, mycelium making holes at *d* and *e*. After Hartig.

Within the tissues the mycelium may cause the disappearance of substances,[339] e. g., Fomes igniarius consumes the tannin, or the mycelium may secrete enzymes which penetrate the host to long distances. These may dissolve first one component of the cell, e. g., the lignin, next the most lignified residue, the middle lamella, resulting in dissolution of the tissue. In other cases the parts of the cell walls other than the middle lamella are first affected and soon shrink resulting in cracks. Fig. 289. Some fungi cause characteristic color changes particularly in those cell walls which are rich in carbon. Parasitism in this group is old since good examples of agarics growing on wood are found as early as in the Tertiary period.[43]

These fungi spread to new hosts by spores borne in various ways; by insects (Trametes radiciperda) animals, wind (Polyporus pinicola) etc., or in a purely vegetative manner by the mycelium which in the form of rhizomorphs (Armillaria mellea) travels through the ground to considerable distances.[340] An excellent summary of the early history of our knowledge of wood destroying fungi is given by Buller.[1, 338]



FIG. 289.—Pine tracheid acted upon by Polyporus schweinitzii. The cellulose has been extracted leaving the walls chiefly lignin. Drying has caused cracks. After Hartig.

The number of species of Agaricales which affect live plants in the ways mentioned above is very great but in many instances research in this field has not yet revealed the true relation existing between the fungi and the woody plants upon which they are found growing; whether they occur as parasites or as saprophytes; whether actually injurious or not. The species given below are mainly

regarded as actually injurious. If more questionable cases were to be included the number would be increased several fold.

Key to Families of Agaricales

Basidia loosely aggregated on a mold-like or arachnoid base, formed from loose floccose hyphæ. . . . . 1. **Hypochnaceæ, p. 402.**

Basidia closely aggregated, forming a compact layer

Hymenium smooth

Sporocarp effused, resupinate or rarely pileate, usually not fleshy. . . . . 2. **Thelephoraceæ, p. 405.**

Sporocarp clavate, the upper portion only sporogenous, usually fleshy. . 3. **Clavariaceæ, p. 412.**

Hymenium variously folded or pitted

Hymenium with teeth, tubercles or tooth-like plates which are sporogenous. . . . . 4. **Hydnaceæ, p. 413.**

Hymenium lining pores

Pores not easily separating from the pileus, which is commonly leathery, corky or punky. . . . . 5. **Polyporaceæ, p. 416.**

Pores readily separating from the pileus which is fleshy. . . . . 6. **Boletaceæ, p. 440.**

Hymenium covering the surface of radiating plates. . . . . 7. **Agaricaceæ, p. 442.**

Hypochnaceæ

Sporophore poorly developed and often indefinite, of loosely woven floccose hyphæ; the basidia clavate, loosely aggregated into an ill-defined hymenium.

In the simplicity of the sporogenous structures the members of the group approach the Hyphomycetes from which they are separated only by their sporophores which are of the nature of basidia rather than of ordinary conidiophores.

A small family of some half dozen genera and sixty species.

KEY TO GENERA OF **Hypochnaceæ**

Spores colorless, smooth, rarely granular
  Basidia with two sterigmata
    Basidia circinate. ..... 1. **Helicobasidium.**
    Basidia not circinate
      Basidia pyriform, beaked. ..... 2. **Urobasidium.**
      Basidia clavate, not beaked ..... 3. **Matruchotia.**
  Basidia with 2-4 rarely 6 sterigmata..... 4. **Hypochnus,** p. 403.
  Basidia with numerous sterigmata
    Sterigmata small. . ..... 5. **Aureobasidium,** p. 405.
    Sterigmata large. ..... 6. **Pachysterigma.**
Spores colored, mostly spiny. ..... 7. **Tomentella.**

Hypochnus Ehrenberg.

Floccose or fungoid, rarely thinly fleshy, spreading over the substratum; basidia clavate; spores colorless, smooth or minutely granular.

This genus which contains half the species of the family, is

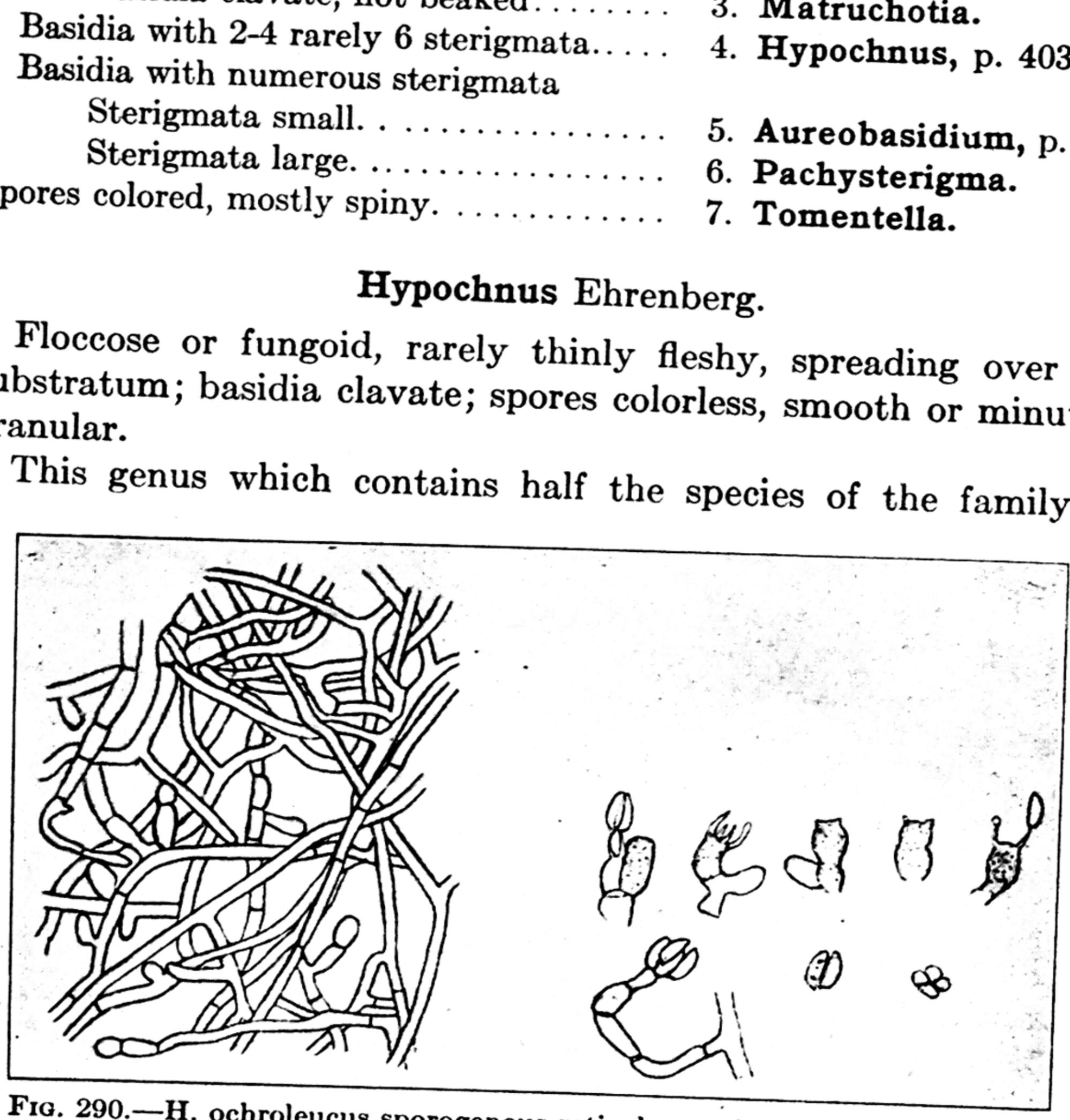


FIG. 290.—H. ochroleucus sporogenous reticulum prior to spore formation. 8 basidia, sterigmata, and spores. After Stevens and Hall.

with difficulty distinguished from Corticium from which it differs in the character of its hymenium.

H. ochroleucus N. [44-46] Sporogenous reticulum of a very close, irregular net work of hyphæ variable in thickness; basidia scattered,

clavate, swollen; sterigmata 4; spores oblong, slightly flattened on the side adjacent to the companion spores, tapering slightly at each end, 4.7–5.8 x 10.5–11.6 μ. A migratory mycelium is present, covering twigs and leaves with a brown felty growth; rhizomorphs white, later buff, about 5.8 μ, septate. Sclerotia are also found.

The long cottony rhizomorphic strands extend along the twigs, up the petioles and in places aggregate to form brown sclerotia,

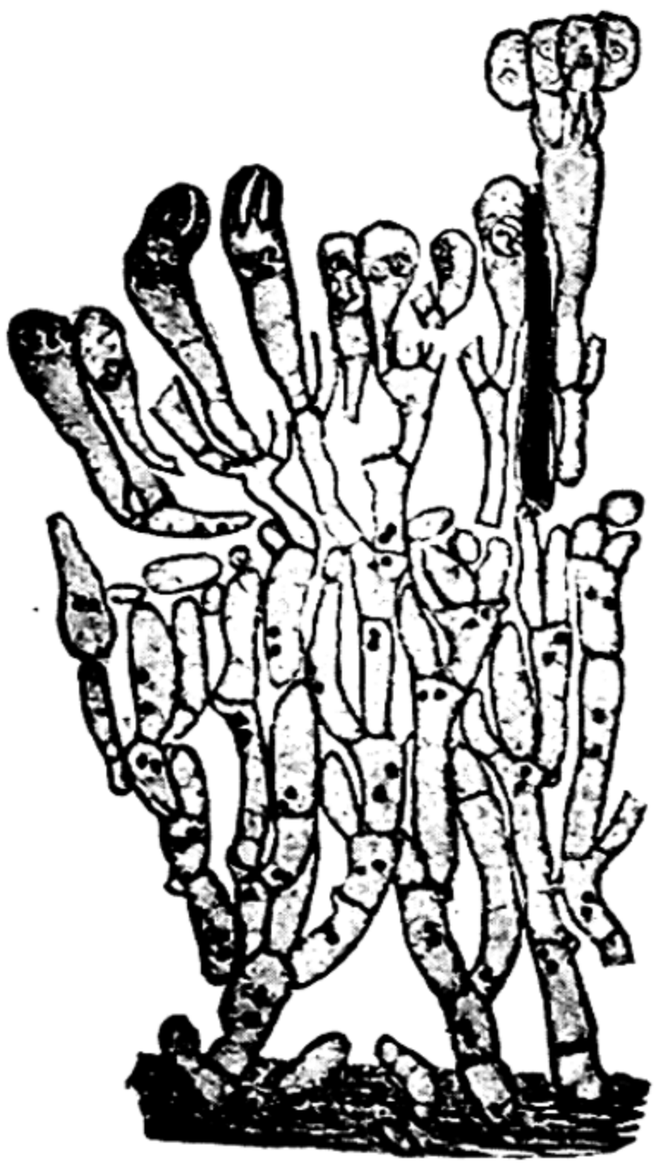


FIG. 291.—Hypochnus, semi-diagrammatic section showing development of hymenium and basidia, with nuclear conditions. After Harper.

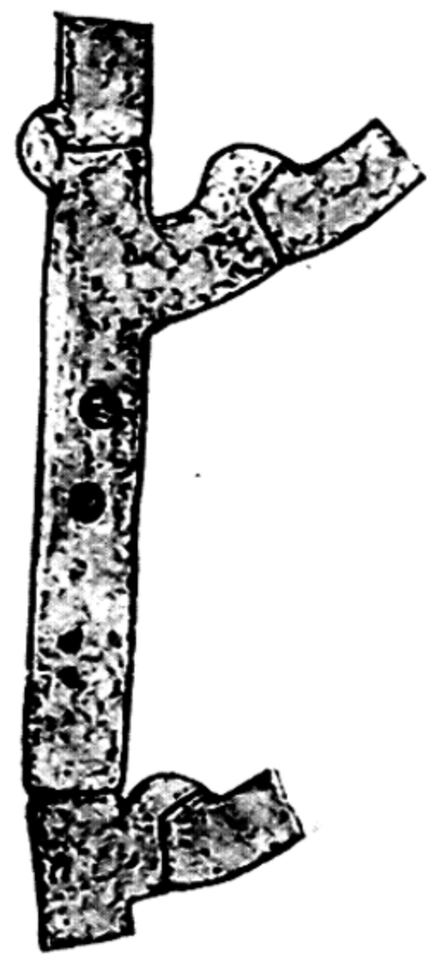


FIG. 292.—Mycelium of Hypochnus showing clamp connections. After Harper.

which are especially abundant near the terminal buds. On the leaves Stevens and Hall [45, 46] describe a loose network from which the basidia arise. Fig. 295. The species is found on apple, pear, lilac, quince, Vibernum and probably other hosts, and is widely distributed.

H. cucumeris Frank.

Fungus gray or brown; basidia elongate, bearing 4 sterigmata; spores ovoid hyaline. Reported on cucumbers [47, 48] in 1883.

H. solani P. & D. is said to be a parasite of potatoes.[49] It is probably identical with Corticium vagum solani. See p. 407.

H. theæ Bern. occurs on tea;[50] **H. filamentosus** Pat. on live leaves of Caryophyllaceæ and Amaryllidaceæ in Quito; **H. fuciformis** (Berk.) McAlp on grasses in Australia.

An undetermined species of Hypochnus was studied by Eustace[51] as the cause of rot of stored apples. Artificial inoculations proved its parasitism, though it was unable to make entrance through sound surfaces.

The spores are hyaline, smooth, usually obovate, 4–5.5 x 2.5–3.5 μ.

Aureobasidium Viala & Boyer[52] (p. 403)

The fungus body consists of delicate, floccose, more or less webby masses of much-branched, septate, golden hyphæ; basidia with numerous sterigmata; spores cylindric.

A single species, **A. vitis**, V. & B., occurs on grape roots in France and Italy[53, 322]

Thelephoraceæ (p. 402)

Sporocarp leathery or membranous, (rarely fleshy, corky or punky) resupinate or pileate, simple or compound; hymenophore smooth, warty or wrinkled; basidia numerous, interspersed with spine-like cystidia.

This is a very large family, but of its eleven hundred species only a few are parasites.

Key to Genera of **Thelephoraceæ**

Hymenophore without cystidia
  Hymenophore entirely resupinate
    Spore membrane colorless
      Contents colorless
        Spores sessile
          Basidia with 2 sterigmata... 1. **Cerocorticium.**
          Basidia with 4 sterigmata.... 2. **Corticium,** p. 406.
          Basidia without sterigmata.. 3. **Protocoronospora,** p. 409.
        Spores stalked..... 4. **Michenera.**
      Contents colored..... 5. **Aleurodiscus.**
    Spore membrane colored
      Hymenophore soon gelatinous.... 6. **Aldridgea.**
      Hymenophore fleshy-leathery.... 7. **Coniophora.**
Hymenophore partially free, shelving
  Context of several layers..... 8. **Stereum,** p. 409.

Context of only one layer
Hymenophore leathery
Hymenium not ribbed
Hymenium almost smooth or with warts
Basidia continuous . . . . . 9. **Thelephora, p. 410.**
Basidia septate . . . . . 10. **Septobasidium, p. 411.**
Hymenium almost smooth . . . . . 11. **Hypolyssus.**
Hymenium with ribs
Ribs becoming warty . . . . . 12. **Cladoderris.**
Ribs with warty spines . . . . . 13. **Beccariella.**
Hymenophore not leathery
Hymenophore gelatinous-fleshy 14. **Phlebophora.**
Hymenophore membranous, rarely fleshy or fleshy-leathery
Hymenium exterior to the hymenophore . . . . . 15. **Craterellus.**
Hymenium inside the hymenophore
Hymenophores mostly solitary
Hymenophore sessile or laterally stipitate . . . . . 16. **Cyphella.**
Hymenophore centrally attached . . . . . 17. **Discocyphella.**
Hymenophores closely grouped . . . . . 18. **Solenia.**
Hymenophore with cystidia
Cystidia of a single cell
Cystidia unbranched
Hymenophore of a single layer
Hymenophore resupinate . . . . . 19. **Peniophora.**
Hymenophore laterally short-stalked . . . . . 20. **Skepperia.**
Hymenophore of several layers . . . 21. **Hymenochæte, p. 411.**
Cystidia stellate-branched . . . . . 22. **Asterostroma.**
Cystidia of several cells . . . . . 23. **Bonïa.**

Corticium Persoon (p. 405)

Hymenophore homogeneous in structure, membranous, leathery or fleshy, almost waxy, rarely approaching gelatinous; hymenium

arising immediately from the mycelium, smooth or minutely warty; basidia clavate, with four sterigmata; spores small, globose or ellipsoid, with a smooth colorless membrane.

A genus of some two hundred fifty species, mostly wood inhabiting.

One species possesses a mycelium which has long been known in its sterile form as a Rhizoctonia.

Corticium vagum solani Burt. [54-56, 324]

Hymenophore, white when sporing, poorly developed, of loosely interwoven hyphæ; basidia short, cylindric or oblong; spores some-

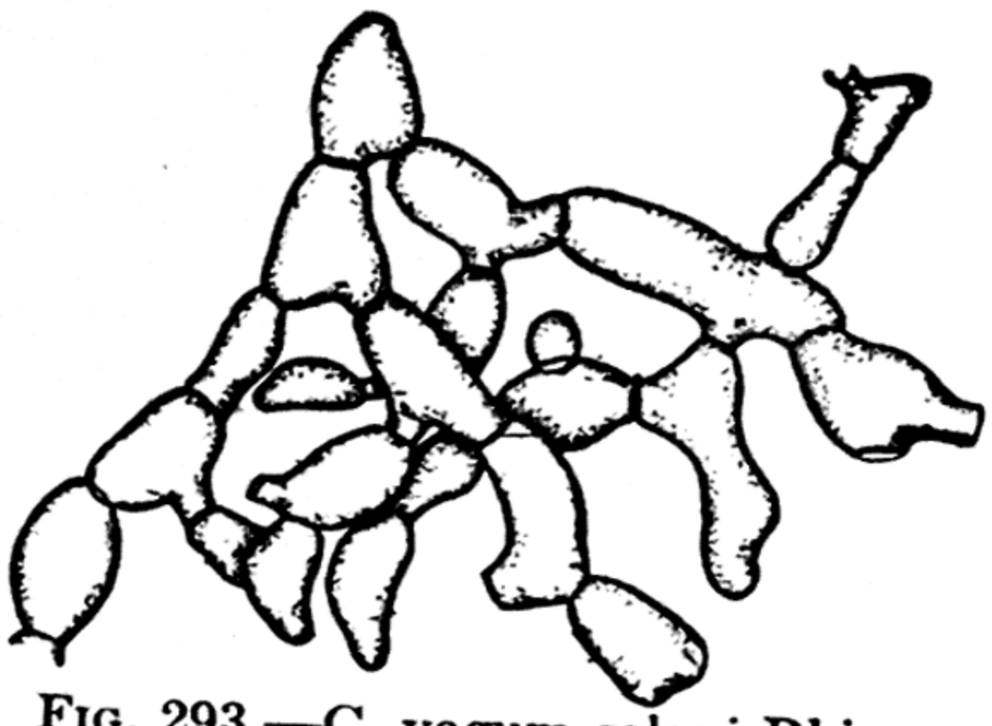


FIG. 293.—C. vagum solani Rhizoctonia stage. After Duggar.



FIG. 294.—*C.* vagum-solani, basidia, sterigmata and spores. After Rolfs.

what elliptic, often irregular in outline, 9–15 x 6–13 μ.

Sterile mycelium (=Rhizoctonia solani=Rhizoctonia violacea) [54] turning yellowish with age, and branching approximately at right angles; often forming sclerotia-like tufts with short, broad cells more or less triangular which function as chlamydospores.

Brown to black sclerotial structures, a few millimeters in diameter, consisting of coarse, broad, short-celled hyphæ of peculiar and characteristic branching also occur freely, both in nature and in culture, Fig. 293. These cells seem capable of functioning as chlamydospores.

The hymenophore consists of a dark network of hyphæ which changes to grayish-white when sporing. It frequently entirely surrounds the green stems of the host near the ground. The tips of the outermost hyphæ are sterigmatate. The spores germinate readily, developing into typical Rhizoctonia mycelium.

The relation which the various Rhizoctonias which have been described on numerous hosts may bear to the one species under

discussion is problematic. Much culture and inoculation work is needed. Some of the various hosts upon which a Rhizoctonia apparently closely allied to that of Corticium vagum solani have thus far been found in America are:

Sugar-beet, bean, carrot, cabbage, cotton, lettuce, potato, radish, sweet potato, pumpkin, watermelon, garden pea, corn, purslane, Solanum verbascifolium, egg plant, pig-weed, spiny pig-weed, Heterotheca subaxillaris, Richardia, Crotalaria, Cyperus rotundus, Heterotheca lamarckii and Phytolacca decandra, Pinus sps.,[341, 342] Picea, Pseudotsuga, carnation and alfalfa.

The sterile mycelium was noted in Europe on potato many years ago; its existence in America has been known since 1890 (Duggar[55]). Its identity with the genus Corticium was demonstrated in 1904 by Rolfs[56] both by observing the connection between the mycelium and the basidia on young potato plants and by culture of the typical Rhizoctonia stage from the basidiospores. The parasitism of the organism was proved by inoculations made with pure culture by Rolfs.[56]

The sterile mycelium (Rhizoctonia) occurs in two forms on the potato, a light-colored actively parasitic form usually somewhat deep in the affected tubers and a darker mycelium growing superficially on the host or over the soil. In artificial culture the manner of branching is typical, the young branches running nearly parallel to the main thread and bearing slight constrictions at their bases.

A key to the species in France is given by Bourdot and Golzin.[164]

C. lætum (Karst.) Bres.

Plant body at first salmon-colored, soon fading to a dirty-white; context, of hyphæ which are nodose, septate, irregular, 4–10 μ, basidia clavate, 35–50 x 7–12 μ; spores oblong ovate, subdepressed on one side, hyaline, 10–14 x 6–8 μ.

On fig and apple in Louisiana, and in Europe and in the Northern United States on Alnus, and Corylus. It causes the limb blight of the fig,[57, 165] gaining entrance through dead twigs. While the fungus is usually a saprophyte, once it gains entrance to the host it follows down the branch, covering it with its bright salmon-colored fructification and causing sudden wilting and dying of the

leaves. The cambium layer is the seat of the disease. The fungus spreads rapidly but is not a serious pathogen except in rainy periods in midsummer.

C. javanicum (Hen.) S. & S. causes disease of coffee and tea;[58] **C. dendriticum** Hen. parasitizes orange stems;[59] **C. comedens** (Nees) Fr. occurs on oak as a wound parasite; **C. zimmermannii** S. & Syd. injures many tropical trees;[60] **C. lilacino-fuscum** Berk. & Curt. occurs on cacao.

C. chrysanthemi Plow. is reported as the cause of death of cultivated chrysanthemum in England.

Protocoronospora Atkinson & Edgerton (p. 405)

Genus as in Corticium, except for the basidia which bear 4–8 sessile, oblong or elliptic spores.

P. nigricans Atk. & Edg.[61] forms narrow elongate spots on vetch pods, stems and leaves. Spot, oblique on the pods, 2–5 x 1–2 mm., at first white or with a purple border, later black; subhymenial layer subepidermal two or three cell layers thick; basidia clavate, to subcylindric, 20–30 x 6–8 μ; spores sessile, pale-pink in mass, oblong to subelliptic, hyaline, smooth, granular, continuous, or 1-septate in germination, straight or curved. Found on vetch at Ithaca, N. Y., associated with Ascochyta.

Stereum Persoon (p. 405)

Hymenophore leathery or woody, persistent, of several layers, sometimes perennial, laterally or centrally attached; hymenium smooth.

A genus of about two hundred fifty species chiefly wood inhabiting, but a few grow in humus.

S. hirsutum (Willd.) Pers.

Hymenophore leathery, firm, expanded, wrinkled, hairy, yellowish; the hymenium yellowish, smooth.

It causes a rot of oak in which the wood appears white-spotted in cross section.

S. quercinum Potter,[62] is found on oak in Europe.

S. frustulosum (Pers.) Fries, though sometimes found on living trees, is confined to dead wood. It causes a speckled rot of oak wood.[67] Fig. 295.

S. purpureum Pers.

Hymenophore expanded, leathery, arched, grayish-white; hymenium smooth, purple.

This species is constantly associated with an English and Canalian disease of drupaceous and pomaceous trees, manifest by a

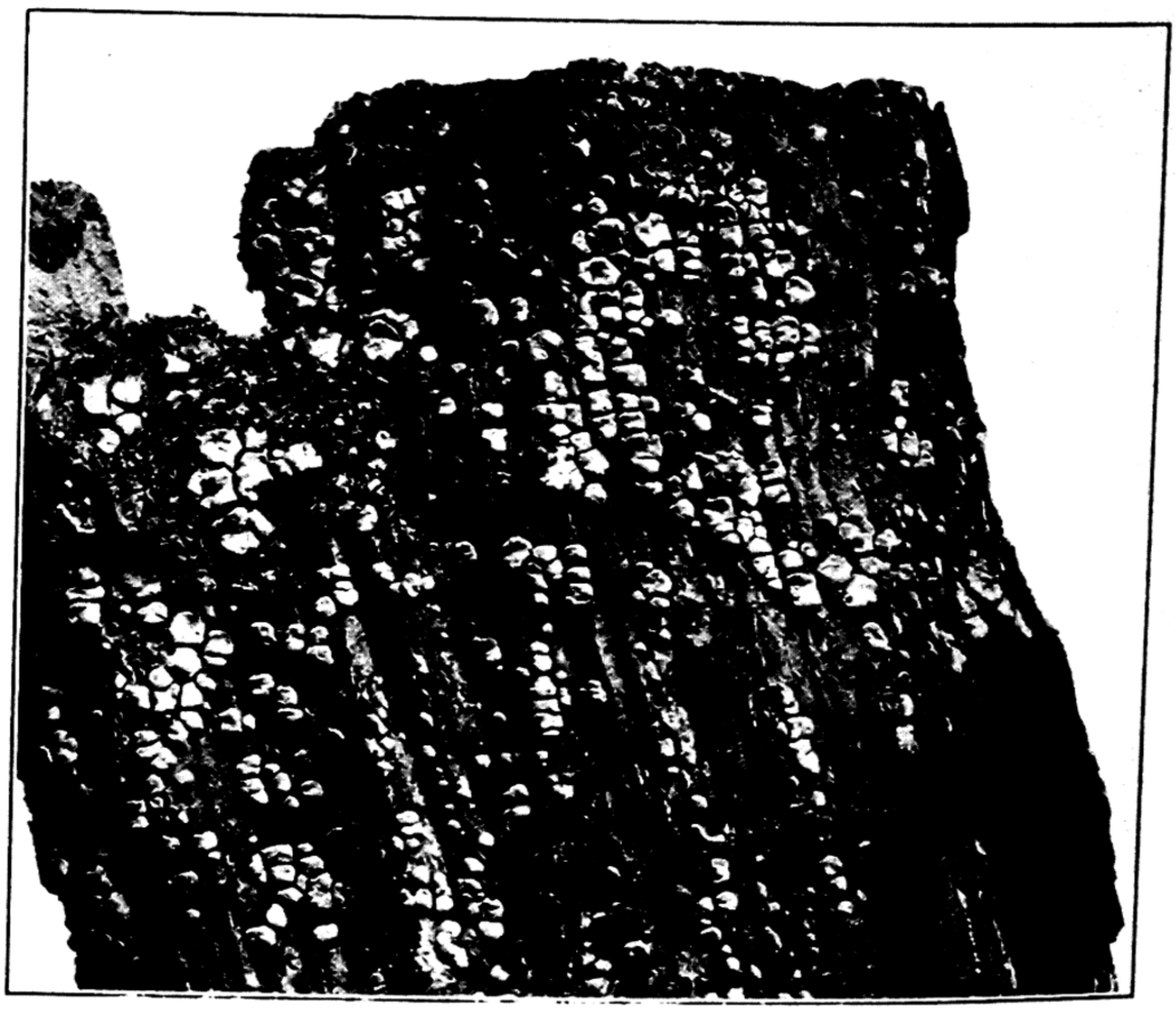


FIG. 295.—Oak timber rotted by Stereum frustulosum. The lighter colored, irregular, small bodies are sporophores. After von Schrenk and Spaulding.

silvering of the leaves, death of branches and finally of the tree. The causal agency of the fungus has not been fully established.[63]

Cosmopolitan in distribution.

S. rugosum Fr. parasitizes the cherry laurel.

Thelephora Ehrenberg (p. 406)

Hymenophore leathery, context similar, variable in form, sessile or pileate, even or more commonly plicate; hymenium confined to the lower surface or extending all over the hymenophore, smooth or uneven, sometimes warty; basidia numerous, clavate; spores elongate, membrane often dull brown, and granular.

T. laciniata Pers. injures various trees by its leathery incrustations.

T. galactina Fr.

Resupinate, broadly effused, encrusted, smooth, milky in color. The root rot on oak is in type much like that caused by Armillaria



FIG. 296.—Telephora laciniata. After Clements.

mellea. It also causes a root rot of apple trees throughout the Central States.[64]

Hymenochætæ noxia Berk. is a practically omnivorous fungus attacking hevea, cacao, tea, dadap, castilloa, Caravonica cotton, bread fruit, camphor, throughout the eastern tropics.

Septobasidium Pat. (p. 406)

As Thelephora but with septate basidia.

S. pedicillata (Schw.) Pat.[65]

Resupinate, effused, byssoid, subcompact, light cinnamon-yellow to white, hymenium smooth.

On oak, palmetto, tupelo, apple, etc. Cosmopolitan.

Clavariaceæ (p. 402)

Hymenophore fleshy, leathery, cartilaginous or waxy, cylindric-clavate, simple or branched often quite large and conspicuous hymenium with cystidia; basidia clavate, with 1 to 4 sterigmata; spores elliptic or fusiform, hyaline.

There are about five hundred species. One genus only is parasitic.

Key to Genera of Clavariaceæ

Hymenophore small, simple
  Basidia with 1 or 2 sterigmata
    Spores colored. ..... 1. **Baumanniella.**
    Spores hyaline
      Hymenophore expanded above into a cap, basidia with 1 sterigma.... 2. **Glœocephala.**
      Hymenophore clavate, basidia with 2 sterigmata. ..... 3. **Pistillaria.**
  Basidia with 4 sterigmata
    Hymenophore clavate or filiform.... 4. **Typhula,** p. 412.
    Hymenophore capitate, hollow. .... 5. **Physalacria.**
Hymenophore usually large, branched, rarely simple
  Hymenophore mostly round, branches never leaf-like
    Hymenophore fleshy. ..... 6. **Clavaria.**
    Hymenophore not fleshy
      Hymenophore cartilaginous or horny. 7. **Pterula.**
      Hymenophore leathery and hairy... 8. **Lachnocladium.**
  Hymenophore leaf-like. ..... 9. **Sparassis.**

Typhula graminum Karst. has been reported as injuring wheat.

Hymenophore fleshy or waxy, delicate, simple or rarely branched, filiform or cylindric, clavate; spores colorless. Sometimes forming sclerotia. Fig. 297.

T. variabilis Riess. is regarded as a parasite of beets.

Hydnaceæ (p. 402)

Sporophore variable in texture, cuticular, leathery, corky, felty, fleshy or woody; free and stipitate, shelving or resupinate; the hymenium warty, thorny, spiny or with tooth-like plates; basidia usually 4-spored, rarely 1-spored.

Over five hundred species, mostly very limited in their geographical distribution, and chiefly epixylous, although some are humus-loving.

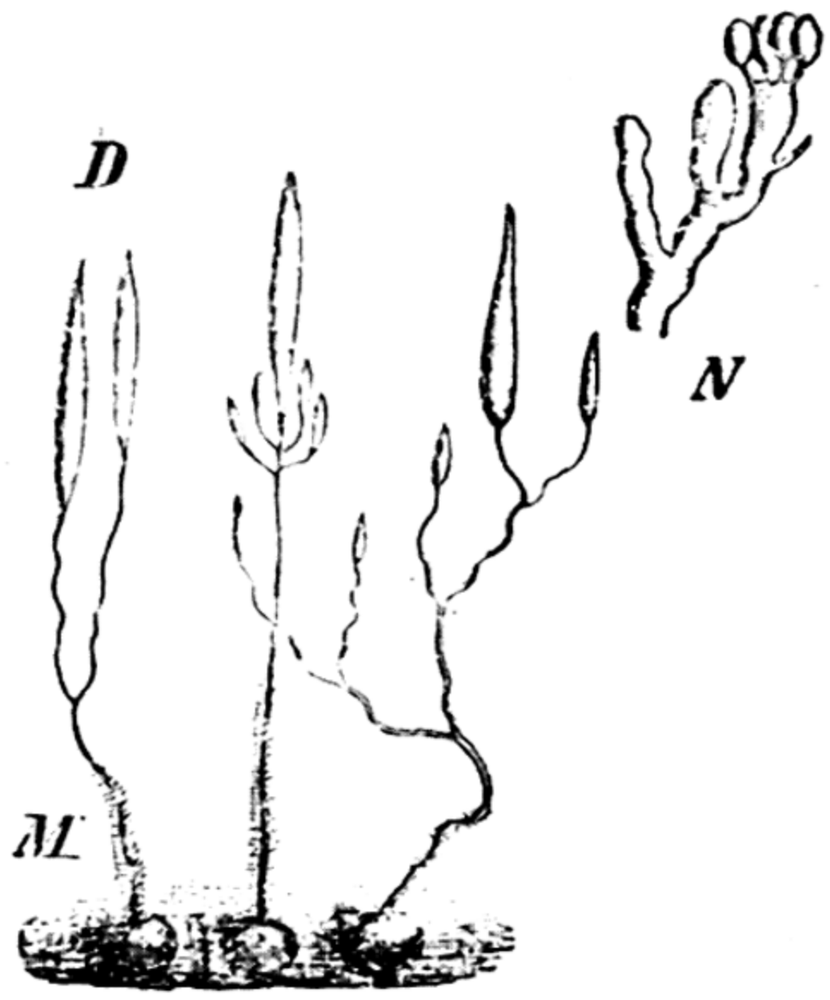


FIG. 297.—Typhula variabilis, *M*, habit sketch; *n*, basidium and spores. After Winter.

KEY TO GENERA OF **Hydnaceæ**

Sporophore annual
Hymenium without a subiculum. . . . . 1. **Mucronella.**
Hymenium with a subiculum.
Hymenium with folds or wrinkles
Crest of the folds entire. . . . . 2. **Phlebia.**
Crest of the folds incised. . . . . 3. **Lopharia.**
Hymenium with granules or warts
Granules penicillate, multifid
Hymenophore fleshy. . . . . 4. **Kneiffiella.**
Hymenophore firm, not fleshy. . . . 5. **Odontia.**
Granules simple
Hymenium porose, reticulate, granular. . . . . 6. **Asterodon.**
Hymenium with obtuse cylindric warts. . . . . 7. **Radulum.**
Hymenium with globose hollowed warts. . . . . 8. **Grandinia.**
Hymenium with more or less subulate teeth or spines
Pileus clavaria-like. . . . . 9. **Hericium.**
Pileus not clavaria-like
Teeth free, mostly fleshy
Teeth rounded.

Spores hyaline	10. **Hydnum**, p. 414.
Spores colored	11. **Phæodon.**
Teeth lammeliform	12. **Sistotrema.**
Teeth connected at base, coriaceous	
Cystidia none	13. **Irpex**, p. 415.
Cystidia present	14. **Hydnochæte.**
Sporophore perennial, punky or woody	
Upper surface smooth, or sulcate	15. **Echinodontium**, p. 415.
Upper surface zonate	16. **Steccherinum**, p. 416.

Hydnum Linnæus

Sporophore cuticular, leathery, corky, woody or fleshy, variable in form, resupinate; pileus, shelving, or bushy branched; hymenium beset with pointed spines; basidia with 4 sterigmata; spores hyaline.

The species of this genus, between two hundred fifty and three hundred, are mostly saprophytes but a few are true parasites on woody plants.

H. erinaceus Bul.[67]

Cap 5–30 cm. wide, white, then yellowish or somewhat brownish, the branches forming a dense head covered with teeth, fleshy; stem short and stout, 2–8 cm. long and thick, or entirely lacking; teeth 3–10 cm. long, slender, densely crowded; spores globose, clear, 5–6 μ. The name refers to the appearance of the head.

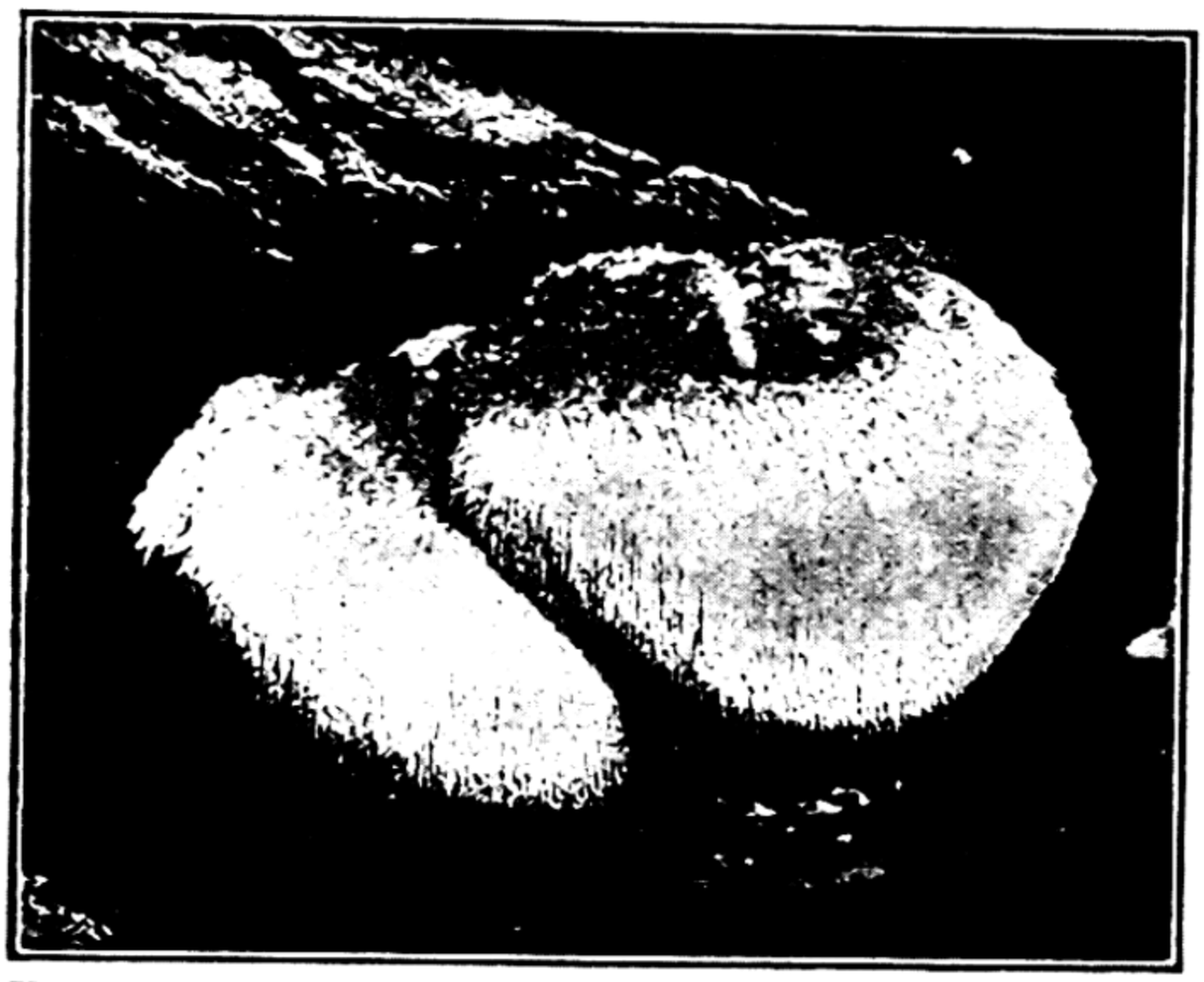


FIG. 298.—Fruiting body of Hydnum erinaceus in a hollow log. After von Schrenk and Spaulding.

It is the cause of a white rot on many deciduous trees, chiefly oaks. The rotted wood is soft and mushy. Numerous large holes filled with masses of light yellowish fluffy mycelium occur in the heart-wood. Sporophores are often absent on the rotted tree.

H. septentrionale Fr.[66]

Sporophores in bracket-like clusters, up to 20–30 cm. wide by

50–80 cm. long, creamy white in color, texture at first fleshy, becoming more fibrous; pileus often 3 cm. thick, upper surface almost plain, slightly scaly, all pilei united behind, teeth slender, often 12 mm. long.

On sugar maple, beech, etc., causing rot of the heart-wood.

H. diversidens Fr.[55] causes white rot of oak and beech in Europe.

H. schiedermayeri Heuff,[68] injures apple trees in Europe.

Irpex Fries (p. 414)

Sporophore shelving or resupinate, hymenium on the lower side, from the first toothed; teeth firm, subcoriaceous, acute, continuous

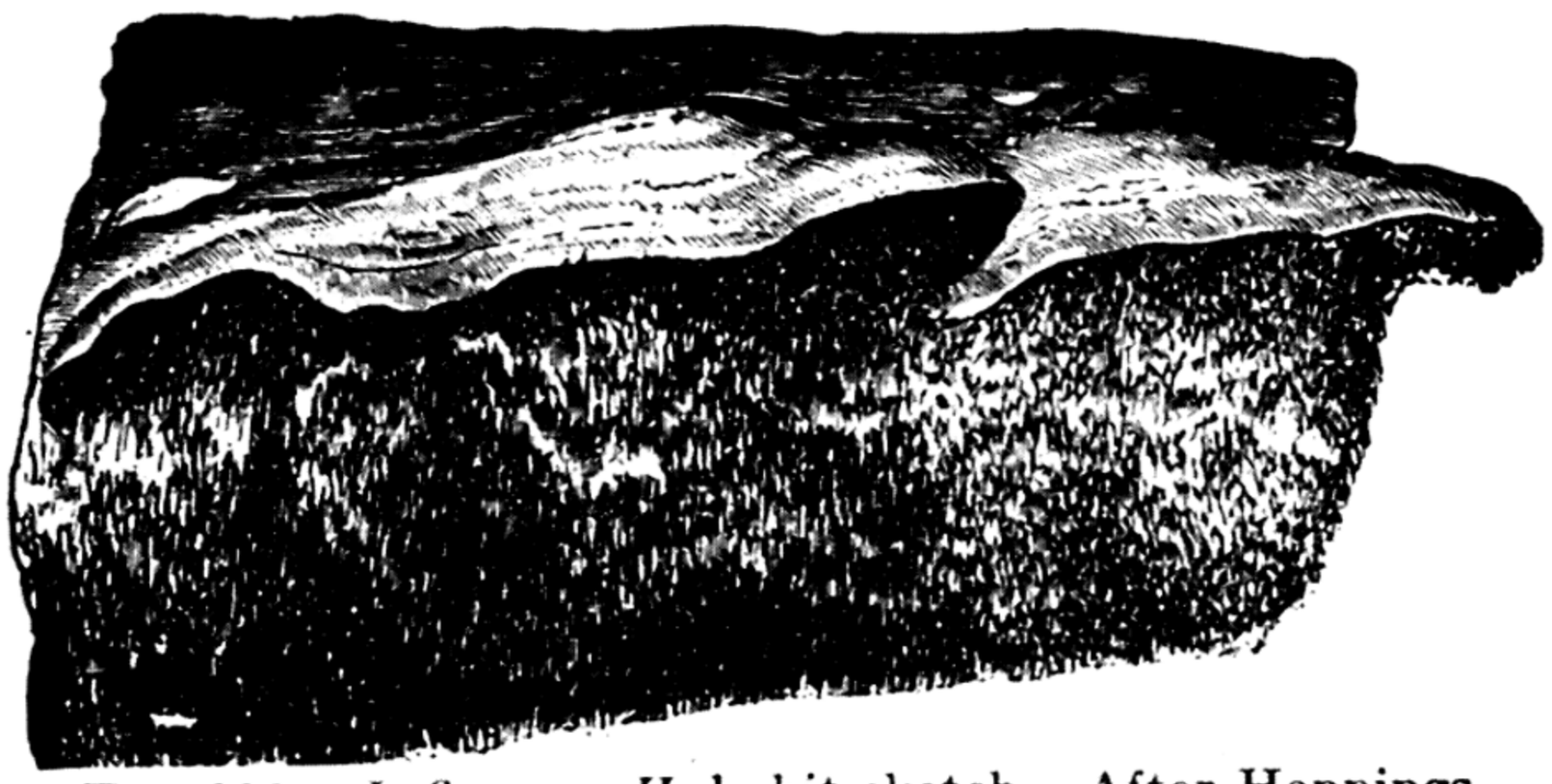


FIG. 299.—I. flavus. *H*, habit sketch. After Hennings.

with the pileus, arranged in rows or reticulately, basally widened and lamellate or even favoid; basidia 4-spored.

I. fusco-violaceus (Schrad) Fr.[69] is a wound parasite on pine in Europe.

I. flavus Klotsch is injurious to the Para rubber, cloves and coffee; **I. destruens** to tea.

I. paradoxus (Schrad) Fr., according to Glazan,[70] causes timber rot.

Echinodontium Ellis & Everhart (p. 414)

Similar to Hydnum but differing in perennial habit; pileus, smooth, woody; cystidia bearing spines.

E. tinctorium E. & E.[71, 334] is the only species.

Spines brown, 1 cm. long, 1½–2 mm. broad; cystidia subconic, reddish-brown, 20–30 x 6–7 μ.

On living trunks of Tsuga, Pseudotsuga [000] and Abies in northwestern North America.

Steccherinum S. F. Gray (p. 414)

Perennial, pileate, sulcate, zonate, radiately subrugose; teeth wide, irregular.

S. ballouii Banker is the single economic species.

Campanulate to subdimidiate, more or less intricate, sessile, decurrent to pendent, 1–4 x 1–5 cm. laterally connate up to 10 cm.; surface velutinous when young, often licheniferous at base, dark olive-brown, drying gray-brown in older parts and seal-brown in younger; margin obtuse, seal brown; substance thin, 1–2 mm., of two layers, the upper harder, somewhat brittle, dark brown, lower softer and lighter colored; hymenium colliculose, golden-yellow, fading to buff or cream; teeth variable, subterete to diform, confluent, papalloid to elongate, usually obtuse, tips brownish, 1–5 x 0.5–1 mm. irregularly distributed; spores hyaline broadly elliptic to subglobose, 7–7.2 x 5.5–6.5 μ.

On Chamæcyparis in New Jersey.[72] According to Ballou [73] this fungus is devastating the forests of swamp cedar in New Jersey. As it grows only in the tops of the tree and dies with the host, the dead sporophores soon disappearing, it is a species not easily observed.

Polyporaceæ (402)

Sporophore annual or perennial; context fleshy, tough, corky or woody; hymenium poroid or lamelloid, fleshy to woody, rarely gelatinous.

The sporophores are sometimes fleshy, even edible but they are more commonly hard and woody, occurring as bracket forms, Fig. 310, on tree trunks.

Key to Genera of **Polyporaceæ**

Pores reduced to shallow pits separated by narrow ridges, folds or reticulations. . .	I. **Meruliеæ**, p. 418.
Pores well developed, variable in size and form.	II. **Polyporeæ.**
Sporophore, at least in part gelatinous	

Sporophore more or less gelatinous throughout. . . . . 1. **Laschia.**
Sporophore leathery above, the pores gelatinous. . . . . 2. **Glœoporus.**
Sporophore leathery, corky or punky, never gelatinous. Pores minute and rounded or large and angular
Sporophore resupinate, never shelving. . . . . 3. **Poria,** p. 418.
Sporophore normally pileate, only accidently resupinate
Pores usually small or medium sized, and round
Substance of the pileus not continuing between the pores
Sporophore at first fleshy, then hardening. . . . . 4. **Polyporus,** p. 418.
Sporophore from the first leathery or spongy usually annual. . . . . 5. **Polystictus,** p. 426.
Sporophore from the first more or less corky or punky, usually perennial. . . . . 6. **Fomes,** p. 428.
Substance of the pileus continued between the pores. . . . . 7. **Trametes,** p. 437.
Pores usually large, hexagonal or labyrinthiform rarely bounded by large plates
Pores hexagonal
Stipe lateral; pores elongate. . . . 8. **Favolus, p. 439.**
Sessile; pores regular. . . . . 9. **Hexagonia.**
Pores labyrinthine, or replaced by plates
Sporophore sessile
Hymenium labyrinthine, becoming irpiciform. . . . . 10. **Dædalea,** p. 439.
Hymenium lamellate, not becoming irpiciform. . . . . 11. **Lenzites,** p. 439.
Sporophore stipitate, concentrically furrowed. . . . . 12. **Cyclomyces.**

Merulius lachrymans of the tribe Merulieæ is said to parasitize violets.[324]

Poria Persoon (p. 417)

Sporophore entirely resupinate, often widely extended, the base leathery to punky, pores small, rounded, covering almost the entire surface.

A genus of almost three hundred species.

P. lævigata Fr. causes a white rot of the birch.

P. vaporaria (Pers.) Fr. is a wound parasite on coniferous trees [74] especially common on spruce and fir causing a brown rot of the sap wood.

P. subacida Pers.[74] Sporophore effused, determinate; margin pubescent, white; pores minute, subrotund, 2–6 mm. oblique, odor subacrid. A common saprophyte on deciduous and coniferous trees especially, pine, hemlock, and spruce. Irregular cavities form within the diseased wood and become lined with a tough felt of hyphæ, yellow on the inner side.

P. hypolaterita Berk. causes a tea disease in Ceylon.[75]

P. vineta Berk. is reported as causing a rot of Hevea in Ceylon.[76]

Polyporus (Micheli) Paulet (p. 417)

Sporophore usually annual; simple or compound, rather thick, fleshy, leathery or corky, stipitate or shelving, pores developing from the base toward the margin. Grading into Polystictus on the one hand and approaching Fomes on the other.

There are about five hundred species.

P. obtusus Berk.[67, 77]

Pileus somewhat imbricate, large and spongy, at length indurate, dimidiate, sessile, often ungulate, 5–7 x 10–15 x 3–5 cm.; surface spongy-tomentose, hirtose, azonate, smooth, sordid-white to isabelline or fulvous; margin very thick and rounded, sterile, entire, concolorous; context spongy-fibrous, white, indurate with age especially below, 1–2 cm. thick; tubes very long, 2–3 cm., white to isabelline within, mouths large, irregular, often sinuous, 1–2 mm. broad, edges thin, fimbriate-dentate to slightly lacerate, white to isabelline, at length bay and resinous in appearance; spores globose, smooth, hyaline, 6–8 μ; hyphæ hyaline, 6 μ; cystidia none.

It causes a heart-rot of living oaks, occurring as a wound parasite and invading the sap wood when decay is well advanced. It is also found on black locust.[332]

P. sulphureus (Bul.) Fr.[55, 67, 78, 74, 79, 80]

Hymenophore cespitose-multiplex, 30–60 cm. broad; pileus cheesy, not becoming rigid, reniform, very broad, more or less stipitate, 5–15 x 7–20 x 0.5–1 cm.; surface finely tomentose to glabrous, rugose, anoderm, subzonate at times, varying from lemon-yellow to orange, fading out with age; margin thin, fertile, concolorous, subzonate, finely tomentose, undulate, rarely lobed; context cheesy, very fragile when dry, yellow when fresh, usually white in dried specimens, homogenous, 3–7 mm. thick; tubes annual, 2–3 mm. long, sulphur-yellow within; mouths minute, angular, somewhat irregular, 3–4 to a mm., edges very thin, lacerate, sulphur-yellow, with color fairly permanent in dried specimens; spores ovoid, smooth or finely papillate, hyaline, 6–8 x 3–5 μ.



FIG. 300.—Polyporus sulphureus. Scattered fruit bodies on living oak. After Atkinson.

It is common as a cause of red heart-rot of forest and shade trees, conifers and deciduous, and also does damage in the orchard, especially on cherry, apple and pear, and in the forest to oak, chestnut, poplar, maple, walnut, butternut, alder, locust, ash, pine, hemlock, larch.

The decayed wood resembles a mass of red-brown charcoal and is characterized by radial or concentric cracks in which the fungus forms thin leathery sheets. In dicotyledons the vessels become filled with the fungus. Round gonidia are often formed within the wood.

P. squamosus (Huds.) Fr.[11, 67, 81]

Sporophore of immense size, reaching 50 cm. in breadth and 3 cm.

in thickness, usually found in imbricated masses projecting from the trunks of living trees. Pileus subcircular and umbilicate when young, soon becoming flabelliform and explanate; surface ochraceous to fulvous, covered with broad, appressed, darker scales

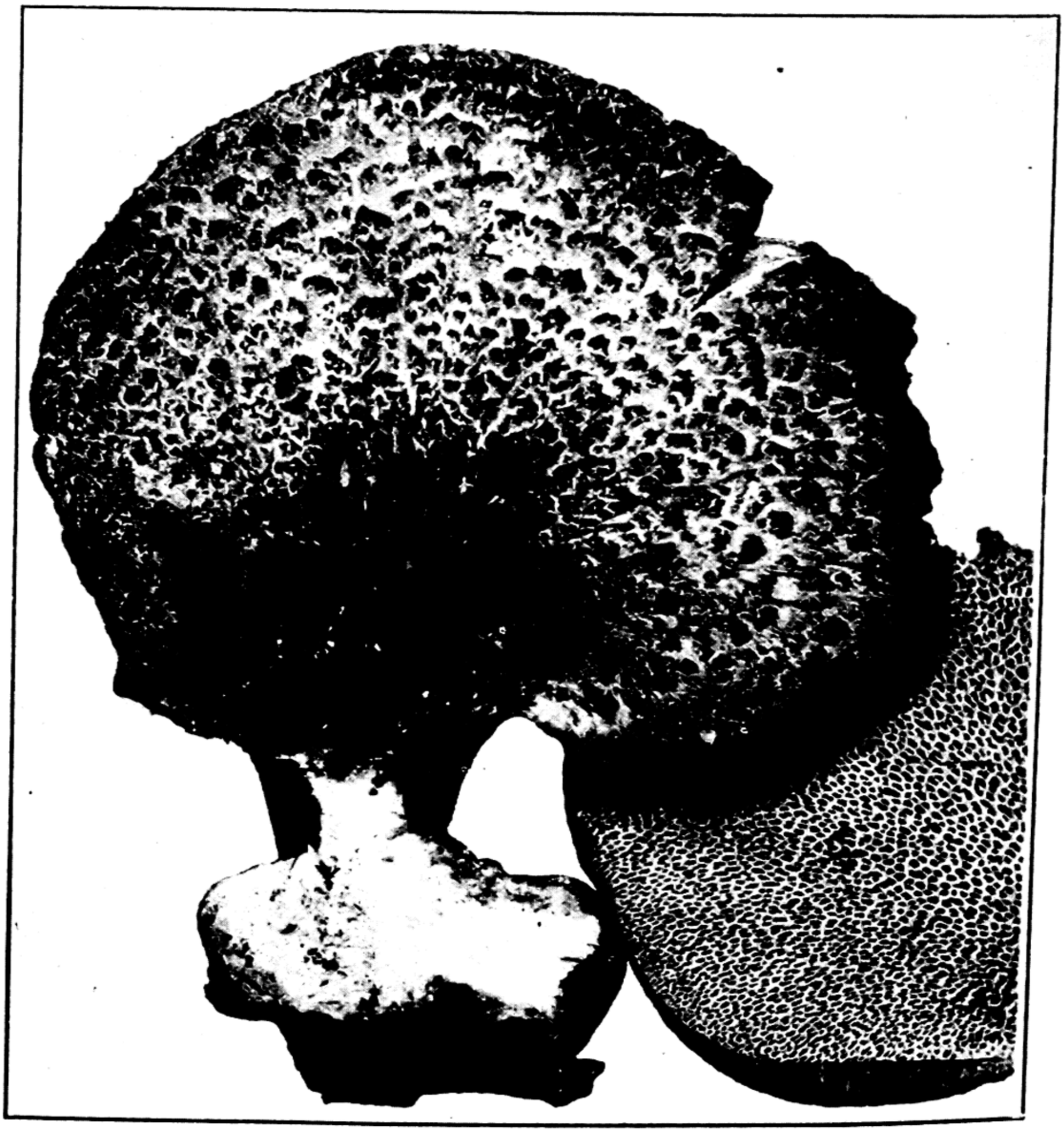


FIG. 301.—Polyporus squamosus. After Clements.

which are very close together in young specimens; margin involute, thin, entire; context fleshy-tough, juicy, milk-white; very thick, odor strong; tubes decurrent, white or pale yellowish, very short, mouths large, alveolar, 1 mm. or more in diameter, edges thin at maturity, toothed at an early age, becoming lacerate: spores broadly ovoid, smooth, hyaline, 5 x 12 μ; stipe excentric to lateral, obese, reticulate above, clothed at the base with short,

dark brown or black, velvety tomentum, often reduced, variable in length.

The mycelium causes white rot of nut, ornamental and fruit trees, particularly maple, pear, oak, elm, walnut, linden, willow, ash, birch, chestnut, beech, growing on dead parts of living trees. The hyphæ advance most rapidly along the wood vessels and often bear clamp connections.

A beautiful biological study has been published by Buller [1, 81] who states that a single sporophore may produce 11,112,500,000 spores and that "the number produced by a single fungus from a single tree in the course of a year may, therefore, be some fifty times the population of the globe."

He showed the following enzymes to be present in the sporophore: laccase, tyrosinase, amylase, emulsin, protease, lipase, rennetase, and coagulase. Pectase, maltase, invertase, trehalase and cytase were not found; It is evident, however, that the mycelium in wood produces cytase and possibly hadromase.

P. hispidus Bul.

Pileus thick, compact, fleshy to spongy, dimidiate, sometimes imbricate, compressed-ungulate, 7–10 x 10–15 x 3–5 cm.; surface hirsute, ferruginous to fulvous, azonate, smooth; margin obtuse, velvety; context spongy-corky, somewhat fragile when dry, ferruginous to fulvous, blackening with age, 1–1.5 cm. thick; tubes slender, about 1 cm. long, ferruginous within, mouths angular, 2–3 to a mm. ferruginous to bay, blackening with age, edges thin, very fragile, lacerate; spores broadly ovoid, smooth, thick-walled, deep-ferruginous, 2–guttulate, 5–6 x 7–8 μ.

It is common on all kinds of deciduous trees, often injuring fruit trees, especially the apple.

P. giganteus (Pers.) Fr. has been reported as injurious to the oak.

P. glivus Fr. is a common saprophyte on deciduous trees and in some cases may be parasitic.

P. dryophilus Berk.

Pileus thick, unequal, unguliform, subimbricate, rigid, 7–8 x 10–14 x 2–3 cm.; surface hoary-flavous to ferruginous-fulvous, becoming scabrous and bay with age; margin thick, usually obtuse, sterile, pallid, entire or undulate: context ferruginous to fulvous,

zonate, shining, 3–10 mm. thick; tubes slender, concolorous with the context, about 1 cm. long, mouths regular, angular, 2–3 to a mm., glistening, whitish-isabelline to dark-fulvous, edges thin,

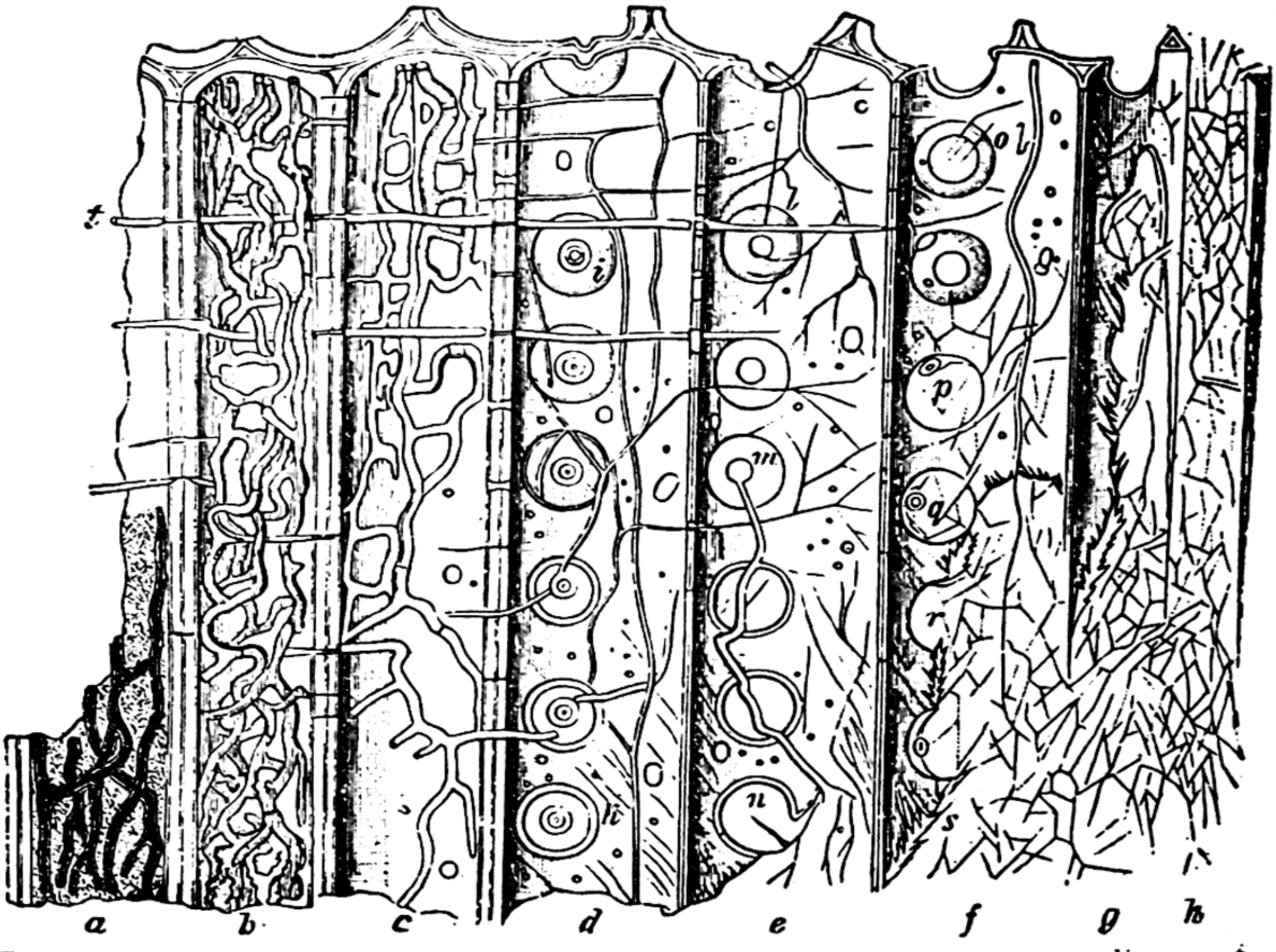


FIG. 302.— Decomposition of spruce-timber by Polyporus borealis. *a*, a tracheid containing a strong mycelial growth and a brownish yellow fluid which has originated in a medullary ray; at *b* and *c* the mycelium is still brownish. At *d* and *e* the walls have become attenuated and perforated, the filaments delicate; at *f* the pits are almost destroyed; at *g* and *h* only fragments of the walls remain." The various stages in the destruction of the bordered pits are to be followed from *i* to *r;* at *i* the bordered pit is still intact; at *k* the walls of the lenticular space have been largely dissolved, their inner boundary being marked by a circle; at *l* one side of the bordered pit has been entirely dissolved; at *m* and *n* one sees a series of pits which have retained a much-attenuated wall on one side only—namely, on that which is provided with the closing membrane. In making the section a crack has been formed in this wall. Between *o* and *r* both walls of the pits are found to be wholly or partially dissolved, only at *p* and *q* has the thickened portion of the closing membrane been preserved; at *d* the spiral structure of both cell-walls is distinctly recognizable. These walls when united form the common wall of the tracheid; at *t* hyphæ are seen traversing the tracheids horizontally. After Hartig.

entire to toothed; spores subglobose, smooth, deep-ferruginous, 6–7 μ; cystidia scanty and short; hyphæ deep-ferruginous.

It causes a disease of oaks.

P. fruticum B. & C. occurs on living twigs of the orange and oleander in Cuba.

P. borealis (Wahl.) Fr.[55, 78]

Pileus sessile, subimbricate, dimidiate to flabelliform, often narrowly attached, spongy to corky, very tough, moist and juicy when fresh, 5–8 x 8–12 x 2–4 cm.; surface uneven, soft and spongy, hirtose-tomentose, azonate, white to yellowish; margin thin, white, entire, somewhat discolored on drying: context fibrous-coriaceous above, fibrous-woody below, white, 0.5–1.5 cm. thick; tubes 4–8 mm. long, white to pallid within, mouths angular, irregular, somewhat radiately elongate, sinuous at times, 1–2 to a mm., stuffed when young, edges thin, white to ochraceous, dentate to lacerate; spores ovoid, smooth, hyaline, 5–6 x 3–4 μ; hyphæ 6–7 μ; cystidia none.

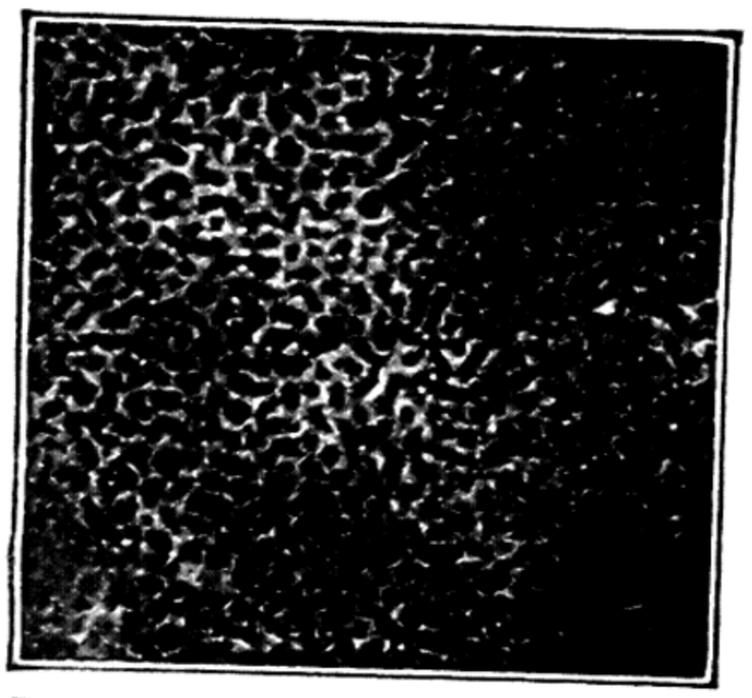


Fig. 303.—Polyporus borealis, hymenium with sinuous pores. After Atkinson.

On pine, spruce, hemlock, balsam pine, etc., as a wound parasite or as a saprophyte on dead trees producing a white rot. The mycelium advances longitudinally, radially and tangentially. At certain stages it is very abundant and forms cords in the channels formed by the fungous enzyme. Later these cords disappear. The young mycelium is stout and yellow, later it is more delicate. Dissolution of the cells begins at the lumen and proceeds outward, the middle lamella persisting last.

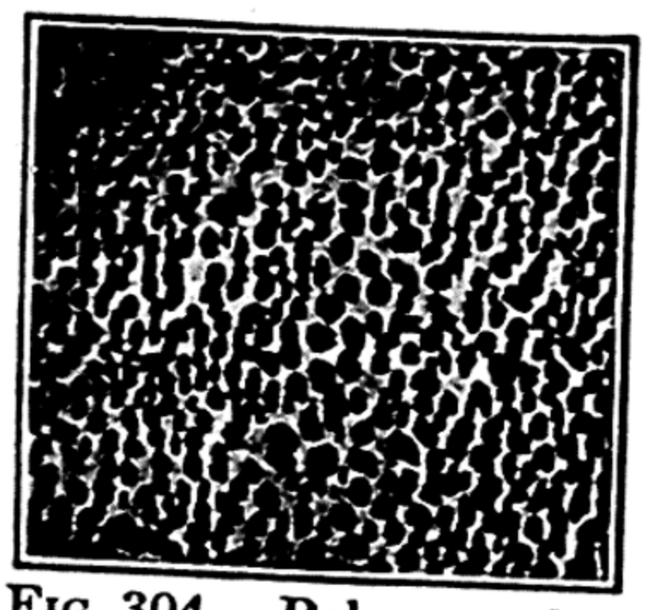


Fig. 304.—Polyporus borealis, hymenium with rounded pores. After Atkinson.

P. dryadeus Fr.[55]

Sporophore very large, sessile, dimidiate, rarely circular, usually imbricate, applanate or depressed above, convex below, fleshy to spongy-corky, rather fragile when dry, 15–30 x 25–65 x 3–5 cm.; surface very uneven, azonate, opaque, hoary-isabelline, anoderm to very thinly encrusted, subshining and bay; margin thick, pallid, entire to undulate, weeping; context thick, zonate, subglistening, ferruginous-isabelline to fulvous, 2.5–4 cm. thick; tubes grayish-umbrinous to fulvous within, 5–15 mm. long, slender, very fragile, mouths whitish when young, becoming somewhat resinous in appearance and finally

bay-brown, at first minute, circular, becoming angular, 4 to a mm., edges thin, fimbriate to lacerate, deeply splitting and separating with age: spores subglobose, smooth, 9–10 x 7–8 μ, the outer wall hyaline, the inner membrane brown; cystidia 15–35 x 5–9 μ.

It causes rot of oak wood in America and Europe.

P. amarus Hedg.[82, 333]

Pileus soft and spongy when young, becoming hard and chalky when old, ungulate, often spuriously stipitate from knot-holes, frequently large, 5–11 x 10–20 x 6–12 cm.; surface pubescent when young, rimose and chalky when old, at first buff, becoming tan and often blotched with brown when older; margin obtuse, frequently having an outer band of darker brown, often slightly furrowed; context creamy-yellow to tan-colored, usually darker in outer layers when old, 4–8 cm. thick; tubes not stratified, brown within, cylindric, 0.5–3 cm. in length, shorter next the margin, mouths circular or slightly irregular, 1–3 to a mm., yellow-green during growth, turning brown when bruised or old, becoming lacerate; spores hyaline or slightly tinged with brown, smooth, ovoid, 3–4 x 5–8 μ, nucleated; cystidia none.

The cause of "pin rot" or peckiness of incense cedar.

P. schweinitzii Fr.[74, 79]

Pileus spongy, circular, varying to dimidiate or irregular, 15–20 cm. broad, 0.5–2 cm. thick; surface setose-hispid to strigose-tomentose and scrupose in zones, ochraceous-ferruginous to fulvous-castaneous or darker, quite uneven, somewhat sulcate, obscurely zonate; margin yellow, rather thick, sterile: context very soft and spongy, fragile when dry, sometimes indurate with age, flavous-ferruginous to fulvous, 0.3–0.7 mm. thick; tubes short, 2-5 mm. long, flavous within, mouths large, irregular, averaging 1 mm. in diameter, edges thin, becoming lacerate, ochraceous-olivaceous to fuliginous, rose-tinted when young and fresh, quickly changing to dark-red when bruised: spores ovoid, hyaline 7–8 x 3–4 μ: stipe central to lateral or obsolete, very irregular, tubercular or very short, resembling the pileus in surface and substance.

On coniferous trees especially spruce, fir, pine, larch, arbor vitæ, entering through the root system and extending up the trunk, causing heart-rot. The tracheids exhibit spiral cracks and fissures

due to the shrinking of the walls. Fig. 289. Diseased wood is yellowish and of cheesy consistency; brittle when dry.

P. betulinus (Bul.) Fr.[67, 83]

Pileus fleshy to corky, compressed-ungulate, convex above,



FIG. 305.—A dead yellow birch tree with fruiting body of P. betulinus. After von Schrenk and Spaulding.

plane below, attached by a short umbo behind, varying to bell-shaped when hanging from horizontal trunks, 5–30 x 5–20 x 2–5 cm.; surface smoky, covered with a thin, separating pellicle, glabrous, devoid of markings, cracking with age; margin velvety, concolorous, obtuse, projecting nearly a centimeter beyond the

hymenium: context fleshy-tough, elastic, homogeneous, 3 cm. thick, milk-white; tubes 0.5 cm. long, 2-3 to a mm., sodden-white, separated from the context by a thin pink layer; mouths very irregular, dissepiments thicker than the pores, obtuse, entire, crumbling away in age, leaving the smooth, white context; spores white, cylindrical, curved, 4–5 μ in length. The mycelium penetrates lignified cell walls entering the living cells and causing death.

On birch it causes a decay of the sap wood similar to that caused by Fomes fomentarius.

P. adustus (Wild.) Fr. is a common saprophyte of deciduous trees.

Polystictus Fries (p. 417)

Sporophore leathery, usually thin; pores developing from the center to the circumference of the hymenophore. The thicker forms are quite close to some species of Polyporus.

About four hundred fifty species.

P. versicolor (L.) Fr.[67, 84]

Pileus densely imbricate, very thin, sessile, dimidiate, conchate, 2–4 x 3–7 x 0.1–0.2 cm.; surface smooth, velvety, shining, marked with conspicuous, glabrous zones of various colors, mostly latericeous, bay or black; margin thin, sterile, entire; context thin, membranous, fibrous, white; tubes punctiform, less than 1 mm. long, white to isabelline within, mouths circular to angular, regular, even, 4–5 to a mm., edges thick and entire, becoming thin and dentate, white, glistening, at length opaque-isabelline or slightly umbrinous: spores allantoid, smooth, hyaline, 4-6 x 1-2 μ; hyphæ 2–6 μ; cystidia none.

Von Schrenk regards this as strictly a saprophyte except when on catalpa, where it causes a heart-rot. It is common on almost any kind of wood.

Catalpa wood under its action becomes straw-colored and finally soft and pithy. Both cellulose and lignin are dissolved.

P. sanguineus (L.) Fr. & **P. cinnabarinus** (Jacq.) Fr. are saprophytes on dead parts of live trees.

P. velutinus (Pers.) Fr. is a common saprophyte which is perhaps sometimes parasitic.

P. occidentalis Klachb. is recorded as a parasite on Pterocarpus indicus in the Malay peninsula.[85]

P. pergamenus Fr.[67]

Pileus exceedingly variable, sessile or affixed by a short tubercle, dimidiate to flabelliform, broadly or narrowly attached, 2–5 x 2–6 x 0.1–0.3 cm.; surface finely villose-tomentose, smooth, white or slightly yellowish, marked with a few narrow indistinct latericeous or bay zones; margin thin, sterile, entire to lobed; context very thin, white, fibrous; tubes 1–3 mm. long, white to discolored within, mouths angular, somewhat irregular, 3–4 to a mm., usually becoming irpiciform at an early stage, edges acute, dentate, becoming lacerate, white to yellowish or umbrinous: spores smooth, hyaline.



FIG. 306.—Polystictus pergamenus. After Clements.

It causes a sap wood rot of practically all species of deciduous trees, often on dead trees, less frequently on living trees which have been severely injured. In general the rotten wood resembles that produced by P. versicolor; microscopically it is seen that the fungus attacks chiefly the lignin.

P. hirsutus Fr.

Pileus confluent-effused, more or less imbricate, sessile, dimidiate, applanate, corky-leathery, rather thick, flexible or rigid, 3–5 x 5–8 x 0.3–0.8 cm.; surface conspicuously hirsute, isabelline to cinereous, concentrically furrowed and zoned; margin at length thin, often fuliginous, sterile, finely strigose-tomentose, entire or undulate: context white, thin, fibrous, spongy above, 1–4 mm. thick; tubes white, 1–2 mm. long, mouths circular to angular, 4 to a mm., quite regular, edges thin, firm, tough, entire, white to yellowish or umbrinous; spores smooth, hyaline, cylindrical, slightly curved, 2.5–3 μ.

It is a wound parasite of the Mountain Ash.[86]

Fomes Fries (p. 417)

Sporophore sessile, ungulate or applanate; surface varnished, encrusted, sulcate, vinose, or anoderm, rarely zonate; context corky to punky; tubes cylindric, stratiose; spores smooth, hyaline or brown.

A genus of some three hundred species.

F. igniarius (L.) Gill.[55, 67, 78, 79]

Pileus woody, ungulate, sessile, 6–7 x 8–10 x 5–12 cm.; surface smooth, encrusted, opaque, velvety to glabrous, ferruginous to

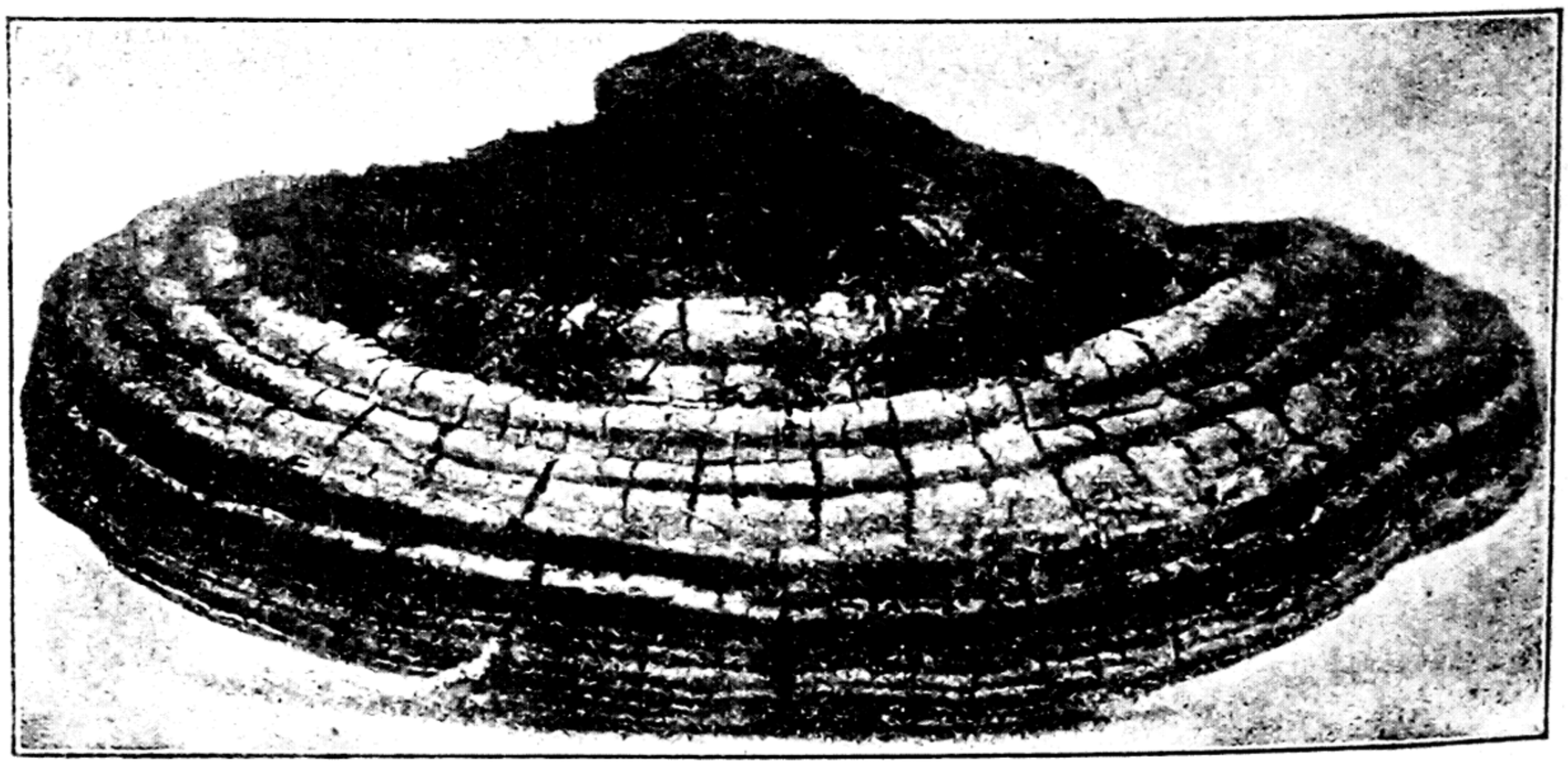


FIG. 307.—Fomes igniarius, from maple. After Atkinson.

fuscous, becoming rimose with age; margin obtuse, sterile, ferruginous to hoary, tomentose; context woody, distinctly zonate, ferruginous to fulvous, 2–3 cm. thick; tubes evenly stratified, 2–4 mm. long each season, fulvous, whitish-stuffed in age, mouths circular, minute, 3–4 to a mm., edges obtuse, ferruginous to fulvous, hoary when young: spores globose, smooth, hyaline, 6–7 μ; spines 10–25 x 5–6 μ.

It is the cause of a white heart-rot, is one of the most widely distributed forms of wound parasites and occurs on more species of broad-leaf trees than any other similar fungus. Among its hosts are beech, oak, apple, peach, willow, aspen, the maples, birch, butternut, walnut, oak, hickory, alder.

The first sporophores usually appear at the point of initial

infection. The mycelium grows mainly in the heart wood but it may gain entrance through the sap wood or encroach upon the sap wood from the heart wood. Its growth may continue after the death of the host. In early stages it follows the medullary



FIG. 308.—A dead beech tree with sporophores of F. fomentarius. After von Schrenk and Spaulding.

rays. The completely rotted wood is white to light yellow and in it the mycelium abounds in the large vessels and the medullary rays. The walls of the affected wood cells are thin and the middle lamella is often wholly lacking, due to solution of the lignin.

F. fomentarius (L.) Fr.[11, 67]

Pileus hard, woody, ungulate, concave below, 7–9 x 8–10 x 3–10 cm.; surface finely tomentose to glabrous, isabelline to avellaneous

and finally black and shining with age, zonate, sulcate, horny-encrusted; margin obtuse, velvety, isabelline to fulvous; context punky, homogeneous, ferruginous to fulvous, conidia-bearing, 3–5 mm. thick; tubes indistinctly stratified, not separated by layers of context, 3–5 mm. long each season, avellaneous to umbrinous within, mouths circular, whitish-stuffed when young, 3–4 to a mm.; edges obtuse, entire, grayish-white to avellaneous, turning dark when bruised: spores globose, smooth, very light brown, 3–4 μ; hyphæ brown, 7–8 μ; cystidia none.

The mycelium kills the cambium and causes a white rot of the sap wood of deciduous trees, especially beech, birch, elm, maple. The wholly rotted wood is soft, and spongy, light yellow and crumbles into its separate fibers.

F. everhartii (E. & G.) [67, 87] (=Pyropolyporus prærimosa).

Pileus woody, dimidiate, ungulate, broadly attached behind, 6–10 x 6–15 x 3–8 cm.; surface glabrous, slightly encrusted, deeply sulcate, not polished, gray to brownish-black, slightly rimose in age; margin obtuse, covered with ferruginous tomentum, becoming gray and glabrous: context corky to woody, repeatedly zoned, fulvous in dried specimens, 2-3 cm. thick; tubes evenly stratified, 0.5–1 cm. long each season, fulvous, mouths circular, 4 to a mm., edges rather thin, entire, ferruginous to fulvous, glistening, the hymenium becoming much cracked in age: spores globose, smooth, ferruginous, 3–4.5 μ; spines abundant, pointed, larger at the base, 15–25 x 6–10 μ.

On black oaks, and walnuts [330] causing a rot almost indistinguishable from that caused by F. igniarius. The mycelium often grows into the living sap wood.

F. carneus Nees.[78, 88]

Pileus woody, dimidiate, varying from conchate to ungulate often imbricate and longitudinally effused, 2-4 x 6-8 x. 0.5-3 cm.; surface rugose, subfasciate, slightly sulcate, rosy or flesh-colored, becoming gray or black with age; margin acute, becoming obtuse, sterile, pallid, often undulate; context floccose-fibrose to corky, rose-colored, 0.2–2 cm. thick; tubes indistinctly stratose, 1-2 mm. long each season, mouths circular, 3-4 to a mm., edges obtuse, concolorous; spores ellipsoid, smooth, thick-walled, subhyaline, 3.5 x 6 μ.

On red cedar and arbor vitæ causing pockets, also on dead spruce and fir. The cellulose is almost all removed from the affected cells of the heart wood. The mycelium is scant and when young is pale and with numerous clamps. It extends horizontally through the tracheids, giving off lateral branches. None is found in the sap wood.

F. annosus (Fr.) Cke.[74, 335] (=Trametes, radiciperda R. Hartig).

Pileus woody, dimidiate, very irregular, conchate to applanate, 10–13 x 5–8 x 0.5–2 cm.; surface at first velvety, rugose, anoderm, light brown, becoming thinly encrusted, zonate, and finally black with age; margin pallid, acute, becoming thicker; context soft-corky to woody, white, 0.3–0.5 cm. thick; tubes unevenly stratified, 2–8 mm. long each season, white, mouths subcircular to irregular, 3–4 to a mm., edges rather thin, entire, firm, white, unchanging: spores subglobose or ellipsoid, smooth, hyaline, 5–6 x 4–5 μ.

On pine, fir and various deciduous trees, described by Hartig[55] as the most dangerous of all conifer parasites. It is not so plentiful in America as in Europe.

The sporophores appear near or on the roots, between the bark scales, where the white felted delicate mycelium also occurs. The spores, carried presumably by rodents, germinate upon the bark of roots; the mycelium penetrates to the living cortex, forces its way into the wood and follows up the stem and down the root. The parenchyma cells are killed and browned; the wood becomes violet, later brownish-yellow. The hyphæ travel in the cell-lumen and pierce the walls. The lignified parts are dissolved first, later the middle lamella disappears. Eventually the whole root system may become involved and the death of the tree result.

F. juniperinus (v. Sch.) S. & Sy.[88]

Pileus woody, ungulate, 3–5 x 5–8 x 5–7 cm.; surface tomentose, deeply sulcate, ferruginous to gray, at length rough and grayish-black; margin obtuse, velvety, melleous or ferruginous to hoary: context corky to woody, reddish-fulvous, 0.5-1 cm. thick; tubes indistinctly stratified, 0.5-1 cm. long each season, melleous within, reddish-fulvous in the older layers, mouths circular to angular, 2–3 to a mm., edges rather thin, entire, even, melleous: spores reddish-brown, smooth; spines blunt, only slightly projecting. On red cedar.

In the holes caused by the fungus in the heart-wood is found a velvety mass of reddish-yellow mycelium, glistening with colorless liquid and holding masses of reddish-brown wood fiber. Long white fibers of cellulose with the lignin removed project into the cavities from the ends.

Structural change begins soon after the mycelium enters a cell lumen. The primary lamella becomes granular and is dissolved by a lignin-splitting enzyme, the secondary lamella becomes white and the cells fall apart.

The mycelium in newly invaded tissue is nearly hyaline and extends lengthwise. Within the tracheids branches are given off in all directions.

The sporophore appears after decomposition is considerably advanced.

F. laracis (Jacq.) Murr.[336]

Pileus firm, at length fragile, ungulate to cylindical, 3–8 x 5–10 x 4–20 cm.; surface anoderm, powdery, white or slightly yellowish, concentrically sulcate, becoming slightly encrusted, tuberculose and rimose; margin obtuse, concolorous: context soft, tough, at length friable, chalk-white or slightly yellowish, very bitter, with the odor of fresh meal, 1–3 cm. thick; tubes evenly stratified, concolorous, 5–10 mm. long each season, mouths circular to angular, 3–4 to a mm., edges thin, fragile, white, becoming discolored and lacerate, wearing away with age: spores ovoid, smooth, hyaline, 4–5 μ; hyphæ 5 μ; cystidia none.

A wound parasite of the larch, pine and spruce in Europe and America.

F. ribis (Schw.) Gill.[89]

Pileus tough, corky, becoming rigid, conchate, laterally connate, 3–5 x 5–10 x 0.7–1.5 cm.; surface rough, velvety, anoderm, indistinctly zoned, ferruginous to umbrinous, becoming glabrous and slightly encrusted with age; margin undulate to lobed, ferruginous, furrowed: context punky, fulvous, 3–5 mm. thick; tubes indistinctly stratified, 1–2 mm. long each season, fulvous, mouths circular, 5–6 to a mm., edges rather thin, entire, ferruginous to fulvous, hoary when young: spores globose or subglobose, pale yellowish-brown, smooth, 3–4 x 3 μ; hyphæ 2.5 μ; cystidia none.

This is a wound parasite on the heart wood of sassafras and is also found on roots and stems of various shrubby plants including rose, gooseberry and currant. The fungus fills the large vessels and tracheids with a brown mycelium and dissolves the entire wall locally.

F. fulvus (Scop) Gill.[67]

Pileus woody, triquetrous, rarely ungulate, thick and broadly attached behind, 1–3 x. 5–7 x 3–8 cm.; surface smooth, very slightly sulcate, velvety, ferruginous, becoming horny and glabrous and finally nearly black with age; margin subobtuse, ferruginous, velvety; context woody, fulvous, 1–2 cm. thick; tubes evenly stratified, 2–3 mm. long each season, fulvous, mouths circular, 3 to a mm., edges obtuse, entire, ferruginous to fulvous; spores globose, compressed on one side, hyaline, 5.5–6 x 4.5–5 μ; spines fulvous, 15–20 x 7–9 μ; hyphæ 2.5 μ.

On plum, birch and other trees.

The decayed wood is red-brown and crumbles when crushed.

F. fulvus oleæ Lin.[19] is injurious on olive in Italy.

F. nigricans Fr.[67, 90] is very similar to F. igniarius from which it differs chiefly in the black upper surface and the bluish or blackish hymenial surface of the sporophores. Murrill [91] regards it as a variety of F. igniarius.

As a wound parasite it causes a reddish-brown heart-rot of deciduous trees, especially of willow, birch, poplar, beech.

F. lucidus (Fr.) Bon. causes a cocoanut root-rot.

F. fraxinophilus (Pk.) Sacc.[67, 92]

Pileus woody, subtriangular, compressed-ungulate, usually decurrent, 5–10 x 6–12 x 2–4 cm.; surface white, pulverulent or finely tomentose, concentrically sulcate, becoming gray or black and rimose with age; margin tumid, white or yellowish, velvety to the touch; context corky to woody, zonate, isabelline, 0.5–1 cm. thick; tubes evenly but indistinctly stratified, 2–4 mm. long each season, white when young, concolorous with the context in the older layers, mouths white, subcircular, 2 to a mm., edges obtuse; spores broadly ellipsoid, smooth, hyaline, thin-walled, 6–7 x 7–8 μ; hyphæ light yellowish-brown, 10-12 μ; cystidia none.

It causes a heart-rot of trunk and branches of species of ash.

The starch in the host cells is lost early by diastatic action in

advance of the fungus, the nearest hyphæ of which may be several millimeters distant, and is replaced by a decomposition product. The mycelium advances through the medullary rays and spreads through spring and summer bands, abstracting the lignin; the middle lamella dissolves and the cells fall apart. Completely rotted wood is straw-colored, very soft, non-resistant. The young hyphæ are very fine and require an immersion less for observation. Clamp connections are frequent. The sporophore appears after the destruction of the wood is considerably advanced.

F. hartigii All. is very similar to, if not identical with, F. igniarius.

It produces a white rot of firs and spruces. The mycelium is yellowish with numerous branches which may fill the cavities of the bordered pits of the tracheids. The middle lamella is eventually dissolved, later the inner walls.

F. robiniæ (Murr.) S. & Sy. [67, 93]

A large fungus with dark rimose surface and tawny hymenium. Pileus hard, woody, dimidiate, ungulate to applanate, 5–25 x 5–50 x 2–12 cm.; surface velvety, smooth, soon becoming very rimose and roughened, fulvous to purplish-black, at length dull-black, deeply and broadly concentrically sulcate; margin rounded, velvety, fulvous; context hard, woody, concentrically banded, 1–3 cm. thick, fulvous; tubes stratose, 0.15–0.5 cm. long, 50 a mm., fulvous, mouths subcircular, edges entire, equaling the tubes in thickness: spores subglobose, smooth, thin-walled, ferruginous, copious, 4–5 μ; cystidia none.

On black locust causing heart-rot, arising from wound infection of living trees. The very hard wood becomes a soft, yellow to brown mass, spongy when wet. The decay extends out in radical lines from the center, along the large medullary rays, killing the cambium and bark on reaching them. The lignin is first dissolved, later the cellulose.

The fungus ceases growth on the death of its host.

F. marmoratus Berk. (=F. fasciatus [Sw.] Cooke.)

Pileus hard, woody, dimidiate, applanate to ungulate, convex above, 7–10 x 8–15 x 2–6 cm.; surface finely tomentose, at length glabrous, concentrically sulcate, at first mole-colored, changing to umbrinous, and finally avellaneous with black fasciations;

margin acute to obtuse, isabelline, sterile, undulate or entire; context punky, thin, ferruginous to fulvous, zonate, 3–5 mm. thick, tubes indistinctly stratified, 5–10 mm. long each season, avellaneous within, mouths circular, minute, 4–5 to a mm. edges obtuse avellaneous to umbrinous, becoming darker when bruised: spores subglobose, smooth, light brown, 5–7 μ; hyphæ brown, 4–6μ; cystidia none.

On water oak and orange in Florida,[94] especially abundant on the former.

F. sessilis (Murr.) Sacc.

A variable fungus with wrinkled varnished cap and acute margin, found on decaying deciduous trees. Pileus corky to woody, dimidiate, sessile or stipitate, imbricate or connate at times, conchate to fan-shaped, thickest behind, thin at the margin, 5–15 x 7–25 x 1–3 cm.; surface glabrous, laccate, shining, radiate-rugose, concentrically sulcate, yellow to reddish-chestnut, at length opaque, dark-brown usually marked near the margin with alternating bay and tawny zones; margin usually very thin and acute, often curved downward, often undulate, rarely becoming truncate, white, at length concolorous: context soft-corky or woody, radiate-fibrous, concentrically banded, ochraceous-fulvous; tubes 0.52 cm. long, 3–5 to a mm., brown within, mouths circular or angular, white or grayish-brown, edges thin, entire: spores ovoid, obtuse at the summit, attenuate and truncate at the base, verrucose, yellowish-brown, 9–11 x 6–8 μ; stipe laterally attached, usually ascending, irregularly cylindrical, 1–4 x 0.5–1.5 cm., resembling the pileus in color, surface and substance, often obsolete.



FIG. 309.—F. pinicola growing on dead trunk of western hemlock. After von Schrenk.

It occurs on oak and maple [95] as a wound parasite, destroying bark and cambium. This and related species are usually saprophytic.

F. pinicola (Fr.) Cke.[67]

Pileus corky to woody, ungulate, 8–15 x 12–40 x 6–10 cm.; surface glabrous, sulcate, reddish-brown to gray or black, often resinous; margin at first acute to tumid, pallid, becoming yellowish or reddish-chestnut: context woody, pallid, 0.5–1 cm. thick; tubes distinctly stratified, 3–5 mm. long each season, white to isabelline,

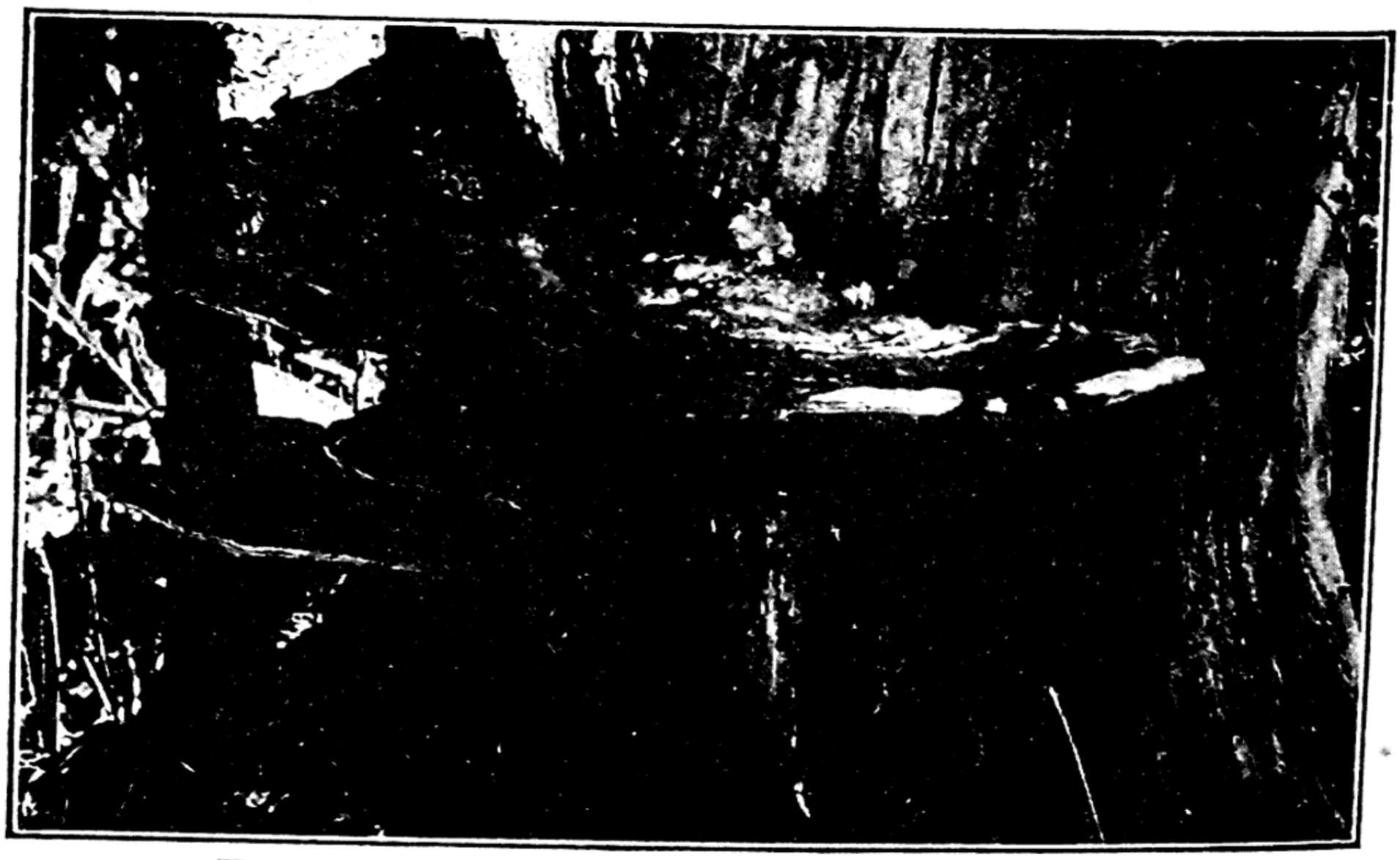


FIG. 310.—Fomes applanatus. After Clements.

mouths circular, 3–5 to a mm., edges obtuse, white to cream-colored; spores ovoid, smooth, hyaline, 6 μ; hyphæ 8 μ; cystidia none.

It occurs on conifers; pine, hemlock, spruce, balsam, larch, etc., more rarely on beech, birch and maple, as a wound parasite of the heart wood. The sporophores are often absent until after death of the host. The tracheids bear many holes. The wood carbonizes, the cellulose is destroyed and sheets of mycelium form, particularly within the space occupied by the medullary rays and in tangential crevices.[96, 329] Fig. 309.

F. applanatus (Pers.) Wallr.

Pileus hard, woody, dimidiate, applanate, 6–15 x 8–30 x 1–4 cm.; surface milk-white to gray or umbrinous, glabrous, concentrically sulcate, encrusted, fasciate with obscure lines, condia-bearing,

usually brownish during the growing season from the covering of conidia; margin obtuse, broadly sterile, white or slightly cremeous, entire to undulate: context corky, usually rather hard, zonate, fulvous to bay, 5–10 mm. thick, thinner with age; tubes very evenly stratified, separated by thin layers of context, 5–10 mm. long each season, avellaneous to umbrinous within, mouths circular, 5 to a mm., whitish-stuffed when young, edges obtuse, entire, white or slightly yellowish to umbrinous, quickly changing color when bruised: spores ovoid, smooth or very slightly roughened, pale yellowish-brown, truncate at the base, 7–8 x 5–6 μ.

It is described by Heald [96] as the cause of rot of both heart and sap wood of living cotton-wood trees. The invaded medullary rays first lose their starch by digestion. Next the lignin is dissolved, then the cellulose.

Von Schrenk regards this fungus as a saprophyte since it grows usually only on outer sap wood that is dead and so far as he observed, it does not cause a true disease.

F. ulmarius Fr. is injurious to elm.

F. semitosus Berk. causes root rot of Hevea in India.

F. australis Fr. is a wound parasite on Acacia in Ceylon.[328]

Trametes Fries (p. 417)

Sporophore annual, rarely perennial, sessile; context homogeneous, coriaceous to corky, extending between the tubes, which are circular or irregular.

There are about one hundred forty-five species.

T. pini (Thore) Fr.[55, 74, 78, 79]

Pileus hard, woody, typically ungulate, conchate or effused-reflexed in varieties, often imbricate, 5–8 x 7–12 x 5–8 cm., smaller in varieties; surface very rough, deeply sulcate, tomentose, tawny-brown, becoming rimose and almost black with age; margin rounded or acute, tomentose, ferruginous to tawny-cinnamon, entire, sterile in large specimens: context soft-corky to indurate, homogeneous, ferruginous, 5–10 mm. thick, thinner in small specimens; tubes stratified, white to avellaneous within, becoming ferruginous at maturity and in the older layers, 5 mm. long each season, much shorter in thin specimens, mouths irregular, circular or dædaleoid, often radially elongate, averaging 1 to a mm., edges

ferruginous to grayish-umbrinous, glistening when young, rather thin, entire; spores subglobose, smooth, hyaline at maturity, becoming brownish with age, 5–6 x 3–4 μ; spines abundant, short, 25–35 x 4–6 μ.

It occurs on pine, spruce, larch, hemlock, and fir as a wound parasite of the heart wood; it is also on willow in Europe and America.

The spores are wind-borne and, lodging on unprotected surfaces, develop a mycelium which grows both up and down, spreading most rapidly in a longitudinal direction, or horizontally following an annual ring. The fungous enzyme first dissolves the lignin leaving the individual tracheids free and of nearly pure cellulose. The cellulose is later dissolved, resulting in holes in the wood. It is found on most of the conifers of the United States as a saprophyte. The wood becomes white-spotted. In late stages of decay the entire wood is full of small holes which are lined with a white fungous felt.

T. ribinophila Murr. is perhaps a parasite on the black locust.



FIG. 311.—Favolus europæus. After Lloyd.

T. theæ Zimm. cause a root-rot of tea in India.[97]

T. suaveolens (L.) Fr.

Pileus large, subimbricate, dimidiate, sessile, convex above, plane or concave below, 4–6 x 5–12 x 1–3 cm.; surface smooth, anoderm, azonate, finely villose-tomentose to nearly glabrous, white to pale-isabelline; margin thick, sterile, entire: context white, punky-corky, 1-2 cm. thick, very fragrant when fresh, with the odor of anise; tubes 5–15 mm. long, white within, mouths circular, 2 to a mm., edges at first very thick, white, entire, becoming thinner and often blackish with age: spores oblong-ovoid, subsinuate, smooth, hyaline, 8–9 x 3–5 μ; hyphæ 7 μ; cystidia none.

On willow.

Favolus Fries (p. 417)

Sporophore leathery, fleshy, or coriaceous, laterally stipitate; hymenium with large elongated pores which may even become lamellate, Fig. 311.

A genus of some seventy species.

F. europæus Fr. is a European parasite of fruit and nut trees; it is also common in America.

Dædalea Persoon (p. 417)

Hymenophore epixylous, usually large and annual, sessile, applanate to ungulate; surface anoderm, glabrous, often zonate: context white, wood-colored or brown, rigid, woody, tough or punky: hymenium normally labyrinthiform, but varying to lamellate and porose in some species: spores smooth, hyaline.

About seventy-six species. Fig. 312.

D. quercina (L.) Pers.

Pileus corky, rigid, dimidiate, sessile, imbricate, applanate, convex below, triangular in section, 6–12 x 9–20 x 2–4 cm.; surface isabelline-avellaneous to cinereous or smoky-black with age, slightly sulcate, zonate at times, tuberculose to colliculose in the older portions; margin usually thin, pallid, glabrous; context isabelline, soft-corky, homogeneous, 5–7 mm. thick; tubes labyrinthiform, becoming nearly lamellate with age in some specimens, 1–2 cm. long, 1–2 mm. broad, chalk-white or discolored within, edges obtuse, entire, ochraceous to avellaneous.

Common on oak and chestnut,[337] often on living trees but growing only on the dead wood.

Lenzites Fries (p. 417)

Hymenophore small, annual, epixylous, sessile, conchate; surface anoderm, usually zonate and tomentose: context white or brown, coriaceous, flexible; hymenium lamellate, the radiating gill-like dissepiments connected transversely at times, especially when young: spores smooth, hyaline. Fig. 313.

About seventy-five species.

L. abietina (Bul.) Fr. occurs on firs. **L. sepiaria** (Wulf.) Fr. has been reported as a parasite on pine, spruce, etc., but recent work of Spaulding [98] shows it to be merely a saprophyte. **L. corrugata** Klot, **L. vialis** Pk. and **L. betulina** (L.) Fr. are common

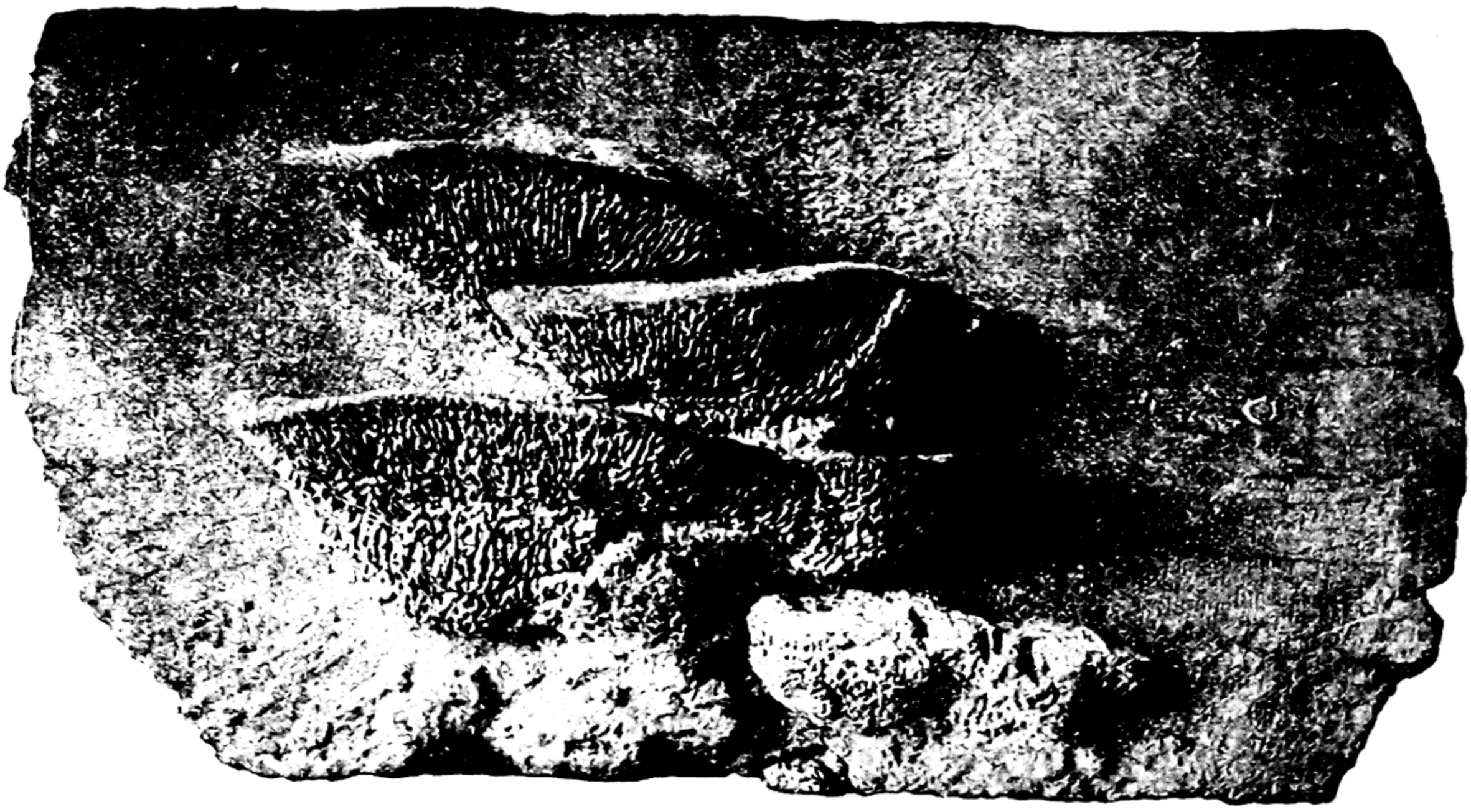


FIG. 312.—Dædalea quercina on oak. After von Schrenk and Spaulding.

saprophytes on deciduous trees; perhaps also parasitic; **L. variegata** Fr. on beech and poplar.

Boletaceæ (p. 402)

Sporophores fleshy, capitate, centrally or laterally stipitate, rarely actually sessile; hymenium on the under surface only, of tubes which separate readily from the pileus and are united to each other or only closely approximated.

A family of less than three hundred species.

KEY TO GENERA OF Boletaceæ

Pores adnate to each other	I. **Boletineæ.**
Pores separate tubes	II. **Fistulineæ.**
Sporophore more or less fleshy	1. **Fistulina,** p. 441.
Sporophore leathery	
Tubes with a central papilla	2. **Theleporus.**
Tubes without papillæ	3. **Porothelium.**

Fistulina Buller (p. 440)

Sporophore fleshy, laterally short-stipitate, hymenial surface at first granular, then each granule becoming a tube; these are approximate but not united; spores brown in mass. Fig. 314.

A genus of a half dozen species.

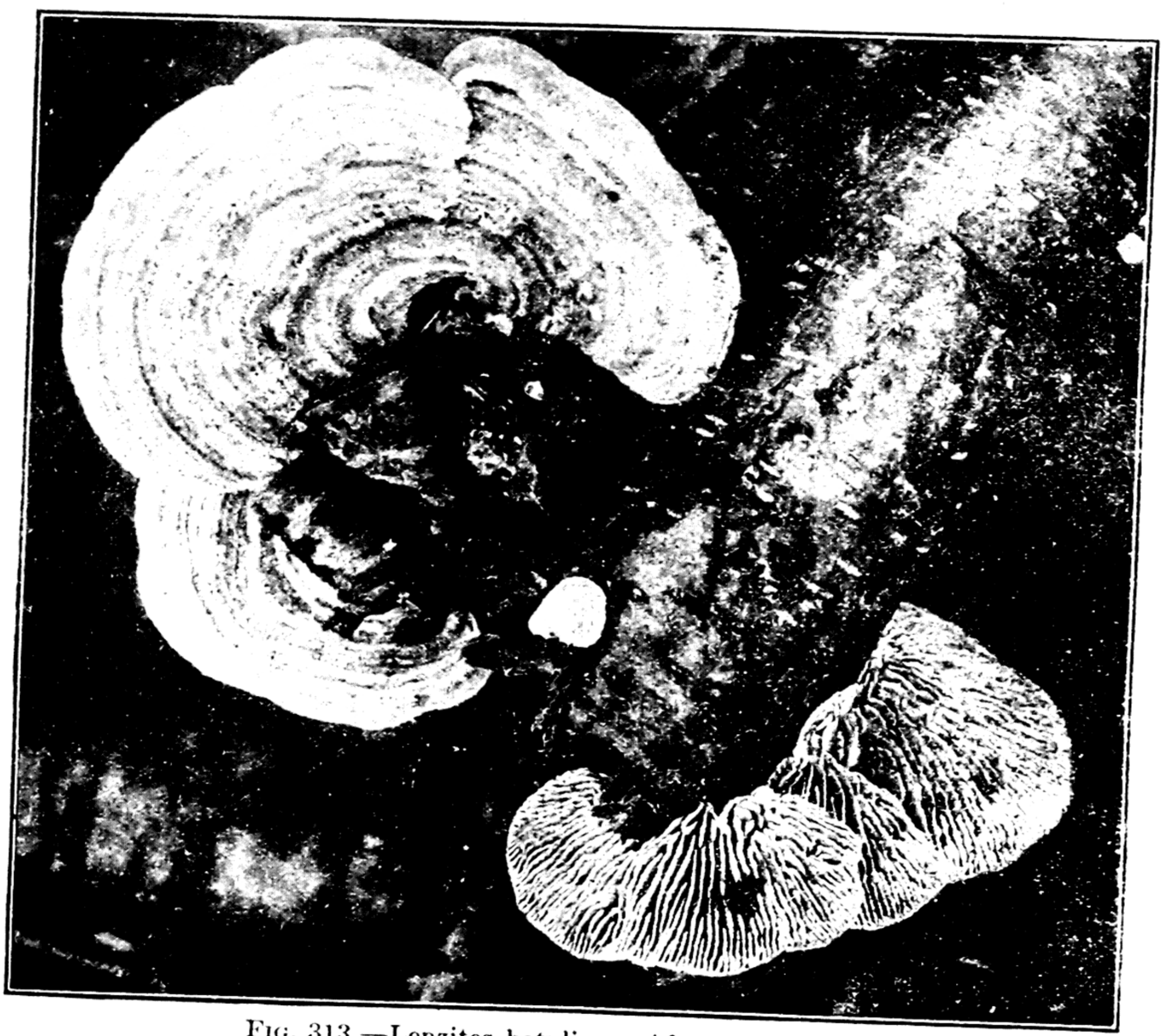


FIG. 313.—Lenzites betulina. After Clements.

F. hepatica (Schä.) Fr.

Cap 8–20 cm. wide, bright-red or red-brown, liver-shaped to shelf-like, more or less lobed, smooth, more or less sticky when wet; flesh containing reddish fibers; stem short, lateral and almost wanting, or sometimes long excentric; tubes pale to yellowish or

pinkish; spores yellowish to pinkish, ellipsoid, 5–7 x 3–4 μ.

It is found on oak and chestnut.

Agaricaceæ (p. 402)[99]

Sporophore usually fleshy, rarely coriaceous or leathery, stipitate or shelving; stipe variable in development, lateral or central,

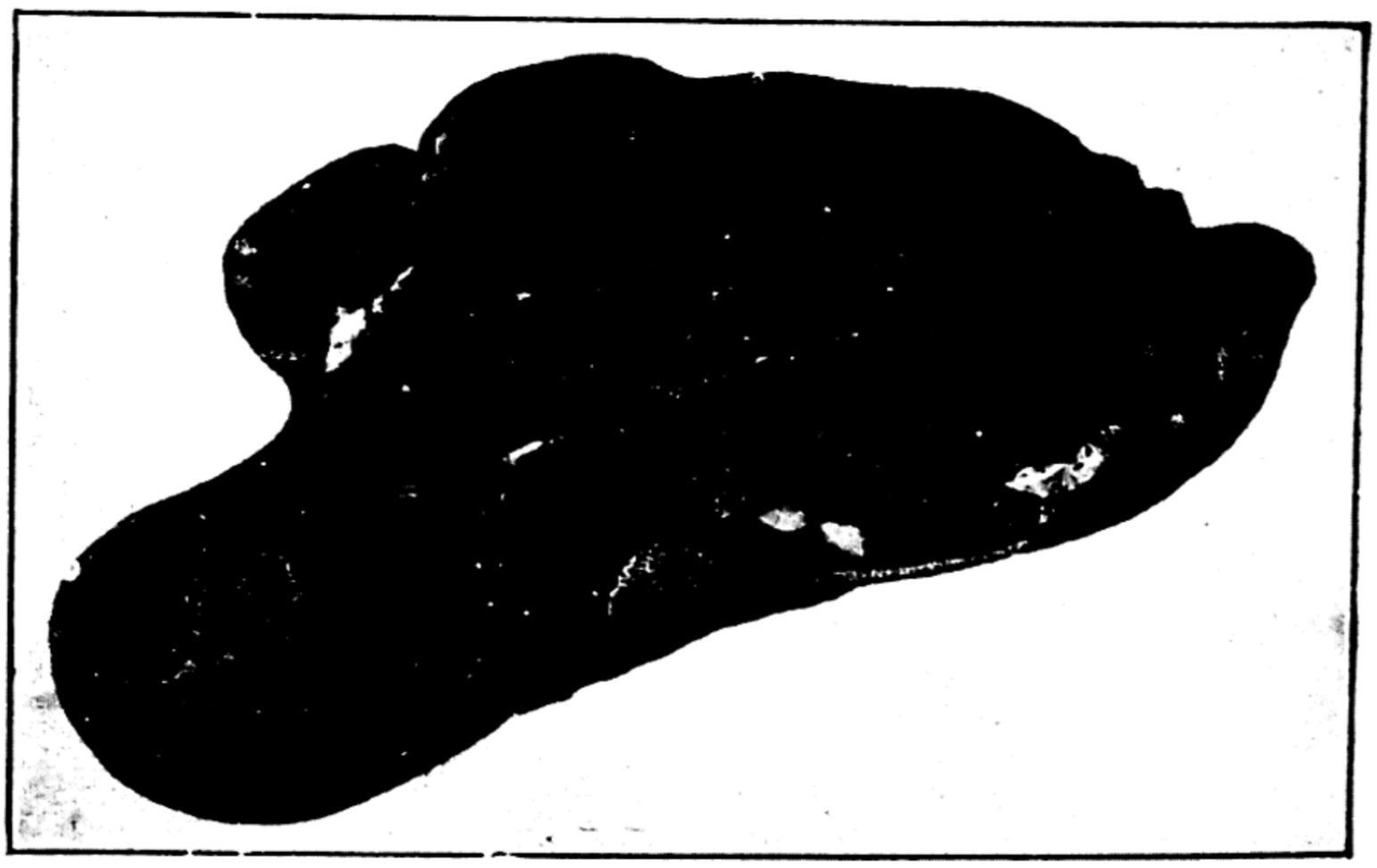


FIG. 314.—Fistulina hepatica. After Clements.

annulate or not, the entire young sporophore often volvate at first; hymenium lamellate, the lamellæ usually free, rarely anastomosing, sometimes dichotomous, rarely reduced to ridges or slight folds.

A family of over twelve hundred species.

KEY TO TRIBES OF Agaricaceæ

Hymenium with the lamellæ ridge or fold-like, imperfectly developed. ..... I. **Cantharelleæ,** p. 443.

Hymenium with normally developed gills

Lamellæ sometimes anastomosing, and forming meshes. ..... II. **Paxilleæ.**

Lamellæ not anastomosing

Lamellæ and often the cap deliquescent (in Montagnites withering,). ..... III. **Coprineæ.**

Lamellæ not deliquescent

Lamellæ thick and fleshy, becoming waxy. ..... IV. **Hygrophoreæ.**

Lamellæ not fleshy or waxy
  Substance of the pileus of two kinds of hyphæ, one thick, tubular and in bundles, the other thin, single and frequently lactiferous. . . . . V. **Lactarieæ.**
  Substance of the pileus of only one kind of hyphæ
    Sporophore at maturity leathery or corky, persistent, rarely fleshy
      Lamellæ at maturity split lengthwise. . . . . VI. **Schizophylleæ,** p. 444.
      Lamellæ at maturity not splitting. . . . . VII. **Merasmieæ,** p. 445.
    Sporophore at maturity fleshy, finally putrescent. . . . . VIII. **Agariceæ,** p. 448.

Cantharelleæ (p. 442)

This tribe is characterized by its low ridge or fold-like lamellæ. The hymenial characters indicate an approach to the Thelephoraceæ.

Key to Genera of Cantharelleæ

Hymenium on the upper side of the pileus. 1. **Rimbachia.**
Hymenium on the under side of the pileus.
  Hymenium with thin veins
    Veins anastomosing. . . . . 2. **Campanella.**
    Veins not anastomosing. . . . . 3. **Arrhenia.**
  Hymenium with thick folds
    Substance of the pileus leathery, tough. . . . . 4. **Trogia,** p. 444.
    Substance of the pileus thin, soft-leathery
      Sporophore sessile, at first saucer-shaped. . . . . 5. **Leptopus.**
      Sporophore laterally stalked, fan-shaped. . . . . 6. **Leptoglossum.**
    Substance of the pileus fleshy. . . . . 7. **Cantharellus.**

Trogia Fries (p. 443)

Cap thin, leathery, or membranous, persistent, sessile, irregular; hymenium of branched folds, the branches chiefly marginal.

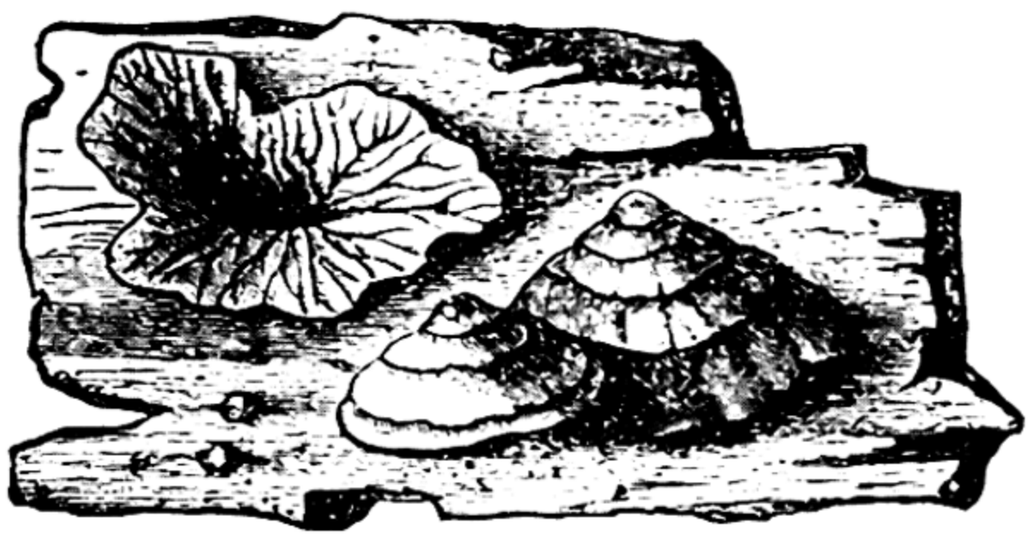


FIG. 315.—Trogia faginea. After Hennings.

There are some seven species.

T. faginea. (Schr.) v. Sch.

Sporophore 1–2 cm. broad, beaker-formed or irregular margined; yellow or orange without, rarely whitish, with fine hairs; ribs concolorous, dichotomous; spores cylindric, 4 x 1–1.5 μ, smooth, colorless.

It injures birch, beech, hazel, etc.

Schizophylleæ (p. 443)

Sporophore, leathery, persistent, the cleft gills with recurved margins. A group of but four genera and less than a score of species.

KEY TO GENERA OF **Schizophylleæ**

Sporophore leathery, sessile.	1. **Schizophyllum, p. 444.**
Sporophore fleshy or membranous, stipitate	
Stipe central	
Cap thin, membranous.	2. **Rhacophyllus.**
Cap fleshy	4. **Œdemansiella.**
Stipe lateral	3. **Pterophyllus.**

Schizophyllum Fries

Cap woolly, upturned, sessile, epixylous; gills cleft, the margins recoiled; texture leathery.

About twelve species. Fig. 316.

S. alneum (L.) Schr.

Cap 1–4 cm. wide, white or gray-woolly, upturned, attached excentrically, irregularly saucer-shaped · stem lacking; gills grayish to purplish; spores subglobose, 2–3 μ.

It parasitizes sugar cane, horse chestnut, chestnut, mulberry [22] and orange.



FIG. 316.—S. alneum. After Clements.

Marasmieæ (p. 443)

Pileus tough, leathery, thin, membranous, or rarely somewhat fleshy, reviving after drying with the return of moisture.

About five hundred fifty species.

KEY TO GENERA OF **Marasmieæ**

Gills leathery-horny; spores black.	1. **Anthracophyllum.**
Gills leathery; spores hyaline	
Pileus not distinct from the stipe; sporophore trumpet-shaped	
Gills forked, edge blunt.	2. **Xerotus.**
Gills with a thin edge	
Gills toothed on the margin.	3. **Lentinus,** p. 445.
Gills with an even margin.	4. **Panus,** p. 446.
Pileus distinct from the stipe	
Annulus wanting	
Pileus firm and dry.	5. **Marasmius,** p. 446.
Pileus somewhat gelatinous.	6. **Heliomyces.**
Annulus present.	7. **Merasmiopsis.**

Lentinus Fries

Sporophore trumpet-shaped, pileus and stipe not distinct, leathery, pileus central or lateral, gills toothed; spores white.

About three hundred forty species.

L. conchatus (Bul.) Schr. is found on birch, poplar, aspen. **L. lepideus** [338] Fr. on pine, birch, etc.



FIG. 317.—Lentinus lepideus. After Clements.

Panus Fries (p. 445)

This genus is very close to Lentinus from which it is separated by the character of the gills which have an entire edge.

P. stipicus (Bul.) Fr. is perhaps parasitic occasionally.[100]

Marasmius Fries (p. 445)

Sporophore tough, withering, often reviving in renewed moisture; pileus, with few exceptions, regular, thin, leathery, without a veil, sharply differentiated from the stipe, rarely sessile or laterally attached; stipe tough, cartilaginous or horny, without an annulus; gills tough, thin, leathery or membranous, entire margined.

Some four hundred fifty species of wide distribution, but chiefly small tropical fungi.



FIG. 318.—Marasmius plicatus. After Fulton.

M. plicatus Wak.

Pileus submembranous, convex or subcampanulate, glabrous, sulcate-striate, chestnut or light wine-colored; gills rather distant, white, basally attached; stipe slender, glabrous above, white downy below.

Marasmius parasitism of sugar cane was first described by Wakker in 1895 [101] later by Howard.[102] In these cases M. sacchari or varieties of it were identified. In 1908 Fulton described M. plicatus Wak. as the cause of serious sugar cane troubles in Louisiana.[103] This fungus which exists first as a saprophyte resides primarily in the soil from which it grows over the stools and eventually penetrates living tissue, destroys many roots and smothers the developing buds. The white mycelium is found cementing the lower leaf sheaths to the cane. It is probable that several species are concerned.

M. sacchari Wak. occurs on sugar cane in the oriental tropics.

M. hawiiensis Cobb. is reported as associated with the preceding species in Hawaii. **M. semiustus** B. & C. affects the stems, peduncles and inflorescence of the banana. **M. equicrinis** Müll. Banc. causes horse-hair blight of cacao and **M. sarmentosus** Fr. a similar disease of the tea plant and of forest trees in India.

Agariceæ (p. 443)

This tribe contains all the gill fungi and is characterized by a fleshy, putrescent sporophore; gills fleshy, rarely tough or leathery, weak, easily broken, not deliquescent, without milky juice. It is the largest tribe of the family. The genera are conveniently grouped as black, brown, rusty, pink or red, and white-spored forms. None of the black-spored species are known as parasites.

Amaurosporeæ (brown-spored series)

With a volva at base. . . . . 1. **Chitonia.**
Without a volva.
  Veil remaining on the stem as an annulus
    Gills free from the stem. . . . . 2. **Agaricus.**
    Gills united with the stem. . . . . 3. **Stropharia.**

Veil remaining attached to the margin of the pileus, often not apparent in very old specimens ..... 4. **Hypholoma,** p. 450.
Veil inconspicuous or wanting
Gills free. ..... 5. **Pilosace.**
Gills decurrent. ..... 6. **Deconica.**
Gills adnate or sinuate
Margin of pileus incurved when young..... 7. **Psilocybe,** p. 451.
Margin of pileus always straight. ... 8. **Psathyra.**

Phæosporeæ (Rusty-spored series)

Annulus continuous
Veil single, forming the annulus. ..... 1. **Pholiota,** p. 452.
Veil double, forming the annulus and deciduous scales on the pileus. ..... 2. **Rozites.**
Annulus arachnoid, filamentous or evanescent, often not apparent in old specimens
Gills adnate; terrestrial. ..... 3. **Cortinarius.**
Gills decurrent; epiphytal. ..... 4. **Flammula,** p. 452.
Annulus wanting
Gills decurrent; stipe with a cartilaginous rind..... 5. **Tubaria.**
Gills not decurrent
Stipe fleshy
Without a volva
Pileus fibrillous or silky ..... 6. **Inocybe.**
Pileus smooth and viscid. ..... 7. **Hebeloma.**
With a volva..... 8. **Locellina.**
Stipe with a cartilaginous rind
Margin of pileus incurved when young..... 9. **Naucoria.**
Margin of pileus straight
Pileus viscid; gills free..... 10. **Pluteolus.**
Pileus not viscid; gills attached. .. 11. **Galera.**

Rhodosporeæ (Pink-spored series)

Stipe lateral..... 12. **Claudopus.**
Stipe central.
Volva present; annulus wanting. ..... 13. **Volvaria,** p. 452.

Volva absent; annulus present. . . . . 14. **Annularia.**
Volva and annulus both wanting
Gills free from the stipe. . . . . 15. **Pluteus,** p. 451.
Gills adnate or sinuate
Stipe fleshy. . . . . 16. **Entoloma.**
Stipe with a cartilaginous rind
Pileus torn into scales. . . . . 17. **Leptonia.**
Pileus papillose, subcampanulate . 18. **Nolanea.**
Gills decurrent on the stipe
Stipe fleshy. . . . . 19. **Clitopilus.**
Stipe with a cartilaginous rind. . . . . 20. **Eccilia.**

Leucosporeæ (White-spored series)

Stipe lateral, or none. . . . . 21. **Pleurotus,** p. 454.
Stipe central
Volva and annulus both present. . . . . 22. **Amanita.**
Volva present; annulus none. . . . . 23. **Amantiopsis.**
Volva absent; annulus present
Gills free from the stipe . . . . . 24. **Lepotia.**
Gills united to the stipe
Pileus usually smooth. . . . . 25. **Armillaria,** p. 455.
Pileus floccose. . . . . 26. **Costinellus.**
Volva and annulus both absent
Gills decurrent on the stipe
Stipe fleshy. . . . . 27. **Clitocybe,** p. 457.
Stipe with a cartilaginous rind. . . . . 28. **Omphalia.**
Gills adnate, stipe with a cartilaginous rind. . . . . 29. **Collybia,** p. 458.
Gills sinuate
Stipe fleshy. . . . . 30. **Tricholoma,** p. 460.
Stipe with a cartilaginous rind
Pileus membranous, more or less striate. . . . . 31. **Mycena,** p. 460.
Pileus very thin, without a pellicle. . . . . 32. **Hiatula.**

Hypholoma Fries (p. 449)

Fleshy; gills attached; annulus imperfect, or none; veil breaking up into fragments which are more or less persistent on the margin of the cap.

About seventy species.

H. appendiculatum (Bul.) Karst. is perhaps parasitic, occurring at the bases of living trees.

H. fasciculare (Huds.) Fr. is said to grow parasitically upon



FIG. 319.—Hypoloma appendiculatum. After Clements.

roots, causing a white rot. It is mentioned as a parasite on raspberry roots in Australia.[104]

H. lateritium (Schä.) Schr. is also possibly parasitic on trees.

Psilocybe Fries (p. 449)

Pileus smooth, margin at first incurved; gills and spores at length brownish or purplish; stipe cartilaginous, hollow or stuffed, veil absent or rudimentary.

About forty species. Fig. 320.

P. spadicea (Schä.) Fr. is a weak wound parasite on various woody plants.

P. henningsii Jung. is said to be occasionally injurious to winter grains [105] in Europe.

Pholiota Fries (p. 449)

Pileus symmetrical, more or less thick, fleshy, with a veil which forms an annulus; gills adnate, becoming rusty at maturity. Fig. 321.

P. aurivilla (Bat.) Quel. and **P. squarrosa** Müll. occur on deciduous trees, especially on the apple.

P. spectabilis Fr. is occasionally parasitic on oaks.

P. mutabilis (Schä.) Quel. is a root parasite on trees.

P. adiposa Fries.

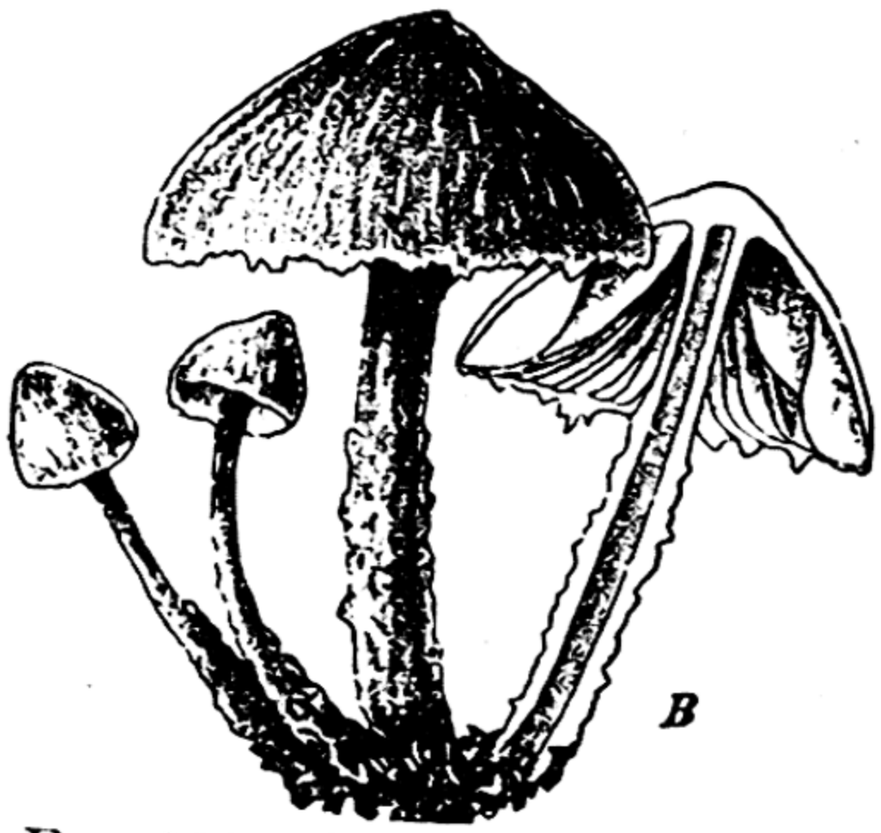


FIG. 320.—Psilocybe pennata. After Cooke.

Cap medium, 5–10 cm. wide, yellow, very sticky when moist, with spreading or erect rust-brown scales which sometimes disappear when old, convex to plane; stem 5–15 cm. by 1–2 cm., yellow, paler above and darker, scaly below the more or less imperfect tufted ring, solid or stuffed; gills adnate, yellowish to rust-colored, broad, crowded; spores rust-colored, elliptic, 7–8 x 5 μ. The name may refer to the sticky cap.

Chiefly a saprophyte, occasionally on living trees, both deciduous trees and conifers, as a wound parasite.

P. destruens Brand. occurs on poplar; **P. cervinus** Schä. on various trees.

Flammula Fries (p. 449)

Pileus fleshy, margin at first incurved; stipe fleshy, fibrous, well marked by the bright yellow or orange colored cap.

About sixty species.

F. alnicola Fr. is probably a root parasite.[100]

F. penetrans Fr. and **F. spumosa** Fr. are regarded by Cavara [106] as root parasites of forest trees.

Volvaria Fries (p. 449)

Fleshy; gills free, white, later pink; spores ellipsoid, smooth;

annulus none; volva present. Easily distinguished from all other pink-spored genera by the volva. Fig. 322.

About thirty-six species.

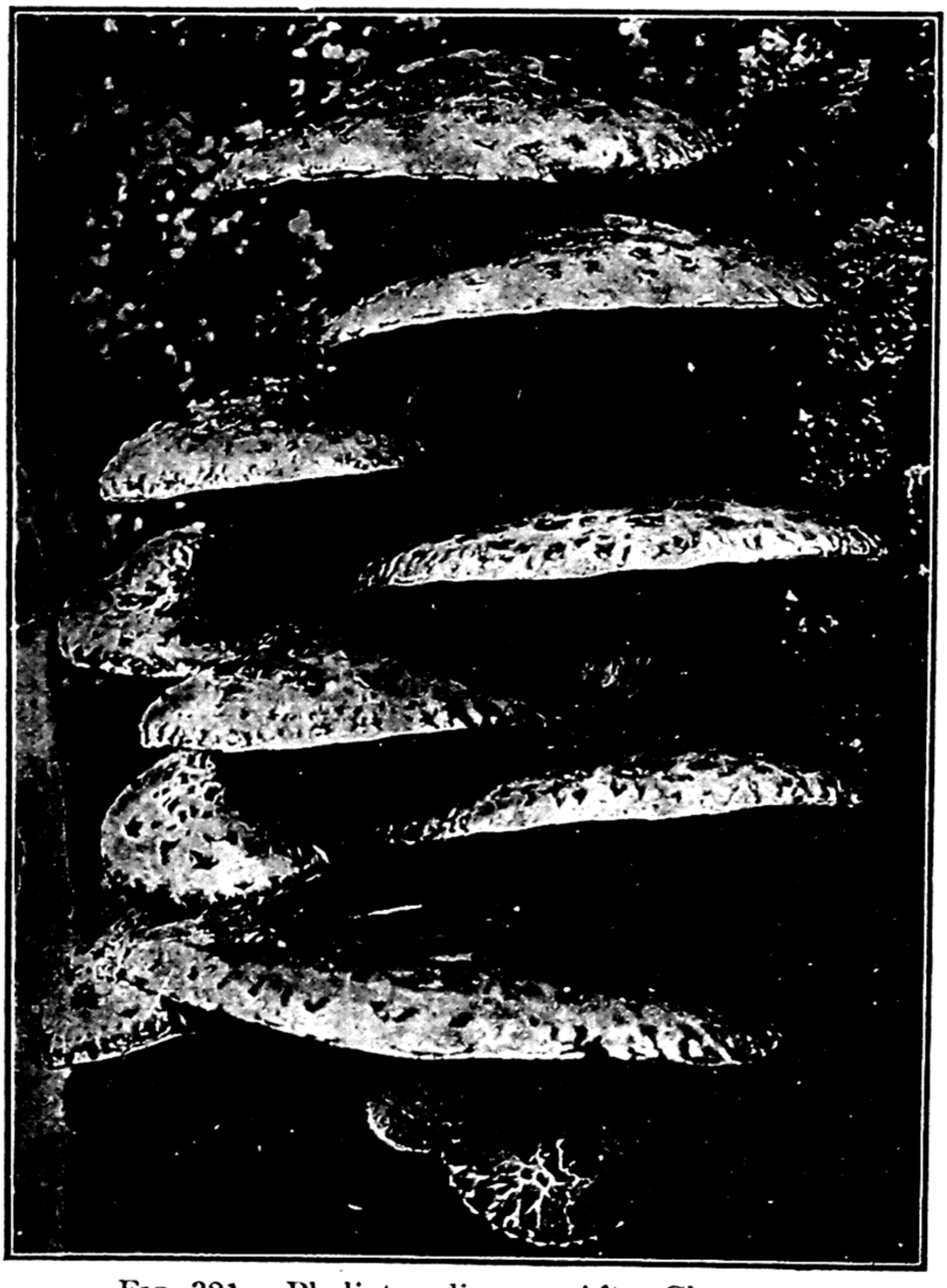


FIG. 321.—Pholiota adiposa. After Clements.

V. bombycina (Schä.) Quel.

Cap large, 8–25 cm. wide, all white and silky, more rarely somewhat scaly, hemispheric or bell-shaped to convex; stem 8–12 cm. by 1–2 cm., white, smooth, tapering upward, solid, volva large and spreading; gills free, salmon-pink, crowded, spores elliptic, 6–7 x 4 μ. It is often parasitic on various trees.

Pluteus Fries (p. 450)

Pileus fleshy, regular; separating easily from the stipe; gills free; volva and annulus both absent; spores elliptic.

P. cervinus Schä. Fig. 323.

Cap large, 5–16 cm. wide, usually some shade of brown, from grayish or yellowish to blackish-brown, more or less fibrous or hairy on the disk, sometimes sticky, convex or plane; stem 7–15 cm. by ½–1 cm., brownish, smooth or black-hairy, solid; gills free, pink, broad; spores pink, rarely greenish, globoid, 7–8 x 5–6 μ.

A common saprophyte which is occasionally parasitic.



FIG. 322.—Volvaria bombycina. After Clements.

Pleurotus Fries (p. 450)

Pileus laterally sessile, or excentrically stipitate. Fig. 324.

A genus of about two hundred fifty species.

P. ostreatus Jacq.

Cap large, 7–24 cm. wide, white, gray or tan, smooth or more or less scaly in age, convex or plane, shelf or shell-shaped, more or less lobed and torn at the margin; stem short and lateral, or none, white, solid, more or less hairy at base; gills long-decurrent, connected by veins on the stem, white or yellowish; spores elliptic, 8–10 x 4–5 μ.

Common on deciduous trees, mainly saprophytic.

P. salignus Schrad. is often parasitic on willow, poplar, mulberry, etc.

P. ulmarius Bul.

Cap large, 8–15 cm. wide, white, whitish or tan, often brownish toward the center, smooth, often cracked, usually convex, sometimes plane; stem long and stout, often nearly central, 5–12 cm. by 2–3 cm., white or tan, smooth or hairy toward the base, solid,

elastic, often curved; gills annexed or sinuate, whitish, broad, close; spores globose, 5–6 μ.

Parasitic on elm and maple or usually a saprophyte.

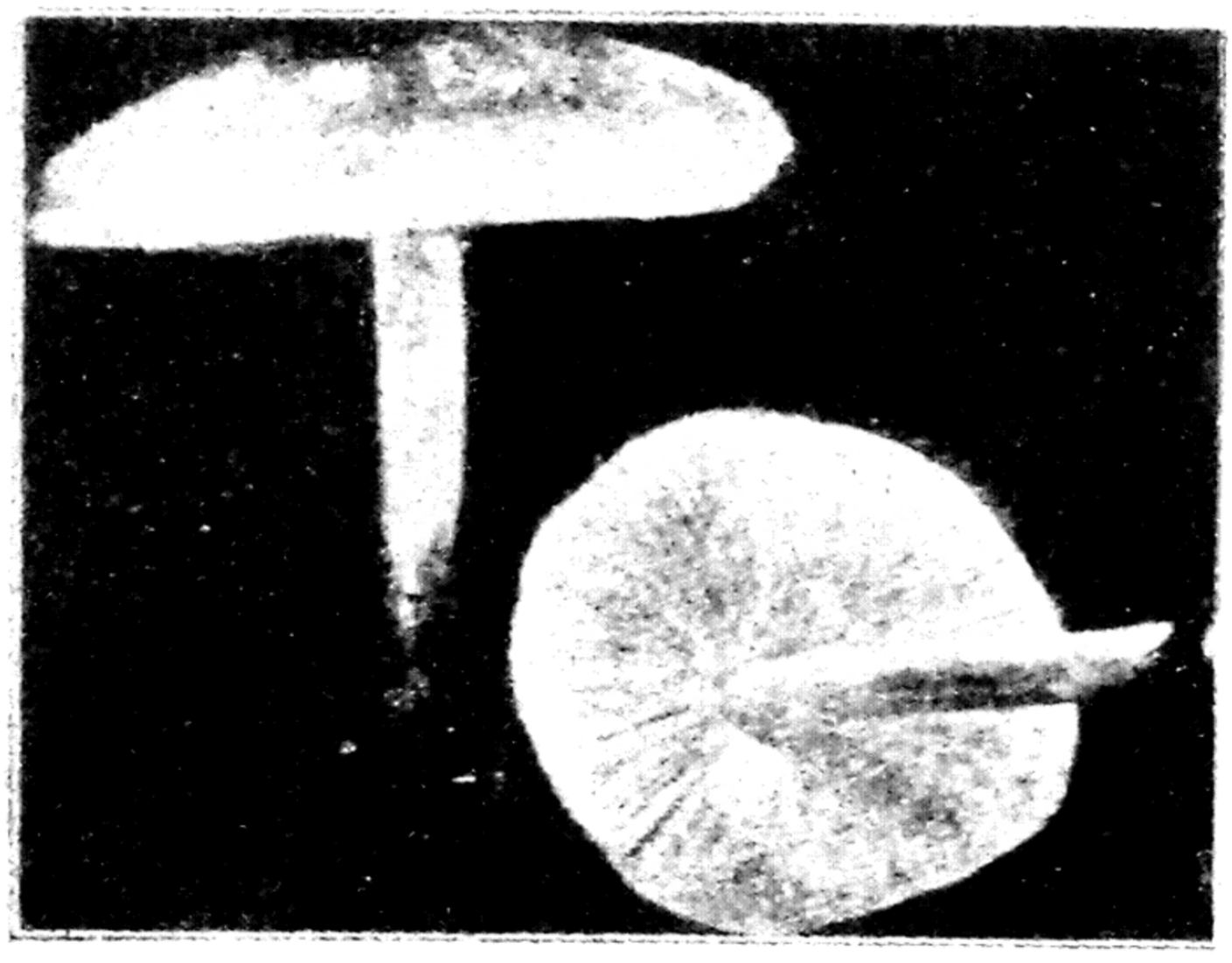


FIG. 323.—Pluteus cervinus. After Clements.

P. nidulans Pers. occurs on roots of trees in Europe.

Other questionable parasites are: **P. atrocœruleus Fr. on willow**; **P. mitis** Pers. on pine; **P. corticatus** Fir. on poplar.

Armillaria Fries (p. 450)

Fleshy, the substance of the pileus and stipe continuous; annulus fixed; gills usually attached, white; spores clavate, ellipsoid or ovate, smooth.

About sixty species. Figs. 325, 326.

An extensive list of members of the genus, under the name Agaricus, found growing upon woody plants has been compiled by Wilcox.[107]

A. mellea (Vahl.) Quel.[67, 80, 11, 55]

Cap large, 3–15 cm. wide, usually honey-colored, but varying through all shades of yellow to brown, typically marked with small tufts of brownish or blackish hairs, especially toward the center, though sometimes woolly or entirely smooth, margin often striate, convex to expanded; stem tall, stout, 3–15 cm. by 6–20 mm., whitish, yellowish, or brownish, especially below the ring, smooth or scaly, hollow or stuffed, ring usually thickish and conspicuous,

but sometimes thin or even lacking; gills touching broadly or running down the stem, whitish or yellowish; spores elliptic or rounded, 7–10 μ.

This is a common wound parasite of conifers and deciduous trees, causing a root-rot. It also causes a potato disease in Australia.[108] The abundant mycelium is white and extends a meter

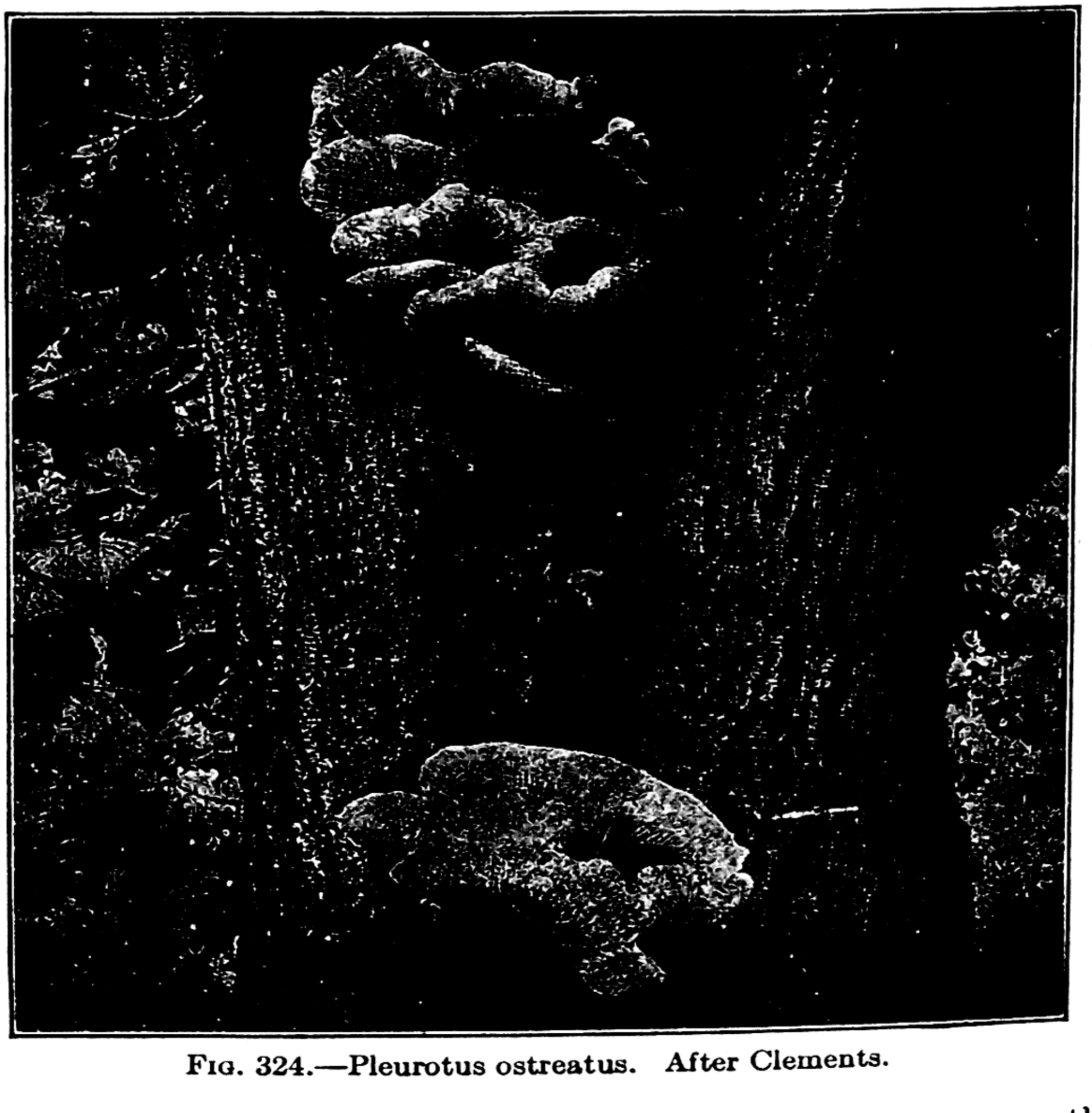


Fig. 324.—Pleurotus ostreatus. After Clements.

or more through the wood and bark, aggregating under or on the bark to form shining hard gray-black intertangled cords (rhizomorphs) 1–2 mm. in diameter often reaching out to great distances through the earth. Fig. 326. Sheets of white felt also occur.

The young mycelium grows into the cambium layer, attacking living cells and often encircling the tree. In the living cortex it presents a characteristic fasciated skin-like appearance.

The sporophores are borne in clusters in autumn on the ground or on the bark.

The spores, sown in plum decoction, develop a mycelium which soon produces rhizomorphs. These advancing give off delicate hyphæ which may penetrate into the host. The mycelium spreads



FIG. 325.—Armillaria mellea. After Clements.

most rapidly through the medullary rays and from them into other tissue elements.

A. fuscipes Petch causes a root disease of Acacia in Ceylon.

A. mucida (Schräd.) Quel. is reported as a wound parasite of the beech.

Clitocybe Fries (p. 450)

Pileus more or less fleshy, margin at first incurved; stipe fleshy, often becoming hollow; gills decurrent.

About ninety species. Fig. 427.

C. parasitica Wil.[107]

Growing in dense clusters; pileus 6–8 cm., convex or umbonate, usually minutely scaly, mottled buff to yellow-brown in color; gills paler, becoming mottled, at first noticeably decurrent; stipe 10–16 cm. high, up to 1 cm. thick, solid, usually curved, darker than the pileus; black rhizomorphs present.



FIG. 326.—Rhizomorphs of A. mellea. After Freeman.

It differs from Armillaria mellea in having no annulus, and in growing in denser clusters.

The fungus causes a root-rot very similar to that caused by Armillaria mellea. There are present typical subcortical strands, mostly between the cortex and cambium and sometimes characteristic subterranean black rhizomorphs adhering close to the cortex of the roots.

Fungous branches enter the wood chiefly through the medullary rays and there is later rapid vertical growth through the vessels and tracheids. The cell contents are destroyed, the hyphæ often forming loops around the nucleus. The sporophores occur in groups at the base of the tree after the disease is well developed. An extensive bibliography is given by Wilcox.[107]

Collybia Fries (p. 450)

Pileus thin, fleshy, margin at first incurved; stipe cartilaginous. About two hundred seventy-five species. Fig. 329.

C. velutipes Curt.

Cap 2–8 cm. wide, yellow-brown or reddish brown, rarely paler except toward the margin, smooth, very sticky when moist, convex to plane or somewhat recurved, often excentric or irregular through pressure.



FIG. 327.—Clitocybe parasitica. After Wilcox

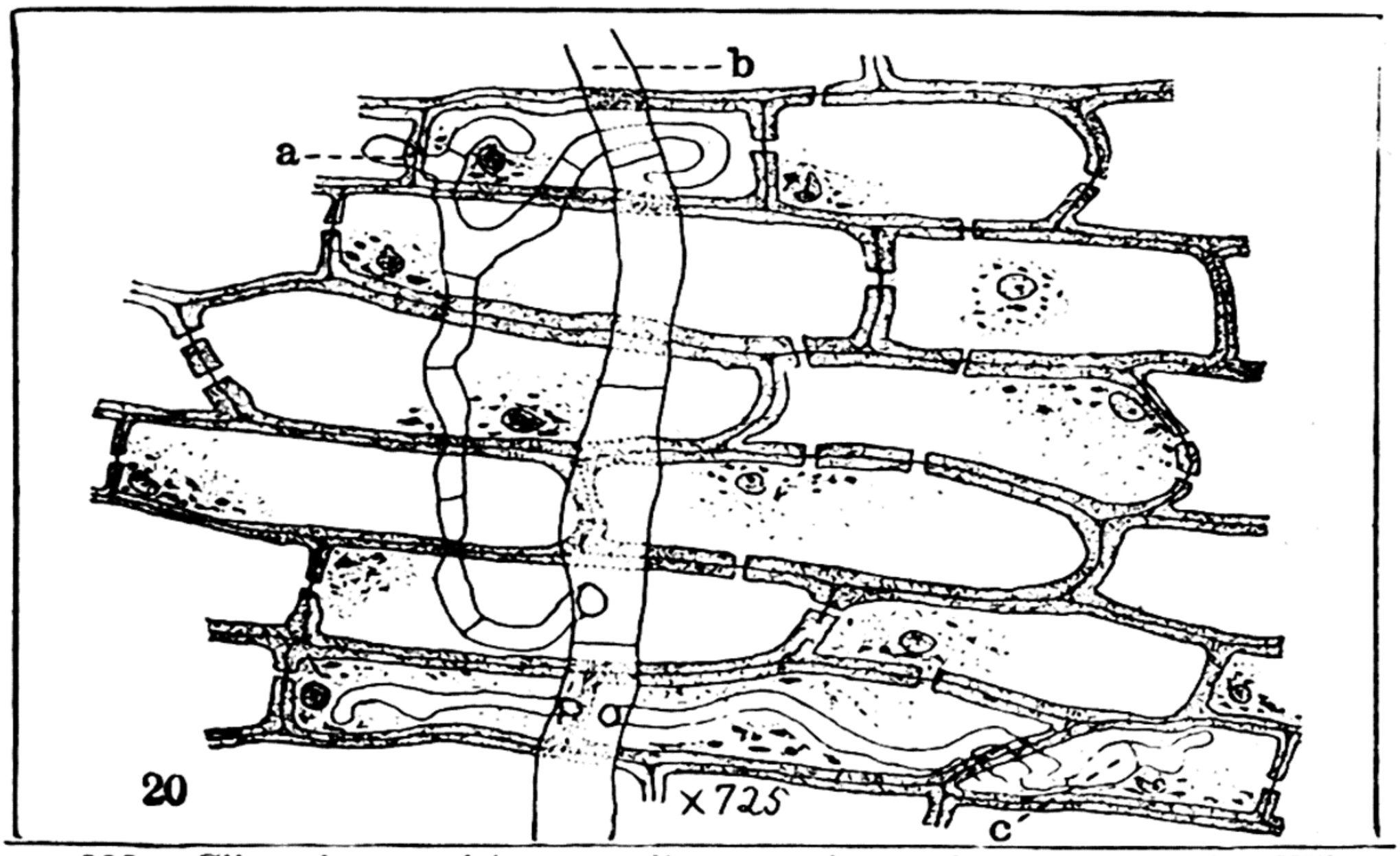


FIG. 328.—Clitocybe parasitica, mycelium entering medullary ray. After Wilcox.

A common saprophyte which is reported by Stewart [109] as the probable cause of death of the horse-chestnut. It has also been reported in Europe as a parasite.



FIG. 329.—Collybia velutipes. After Lloyd.

Tricholoma Fries (p. 450)

Stout and fleshy, stipe and pileus of the same substance; gills sinuate or adnate. Fig. 330.

T. rutilans Schä. occurs on pine roots; **T. saponaceum** Fr. on various tree roots.

Mycena Fries (p. 450)

Small; pileus usually bell-shaped, rarely umbilicate, membranous and more or less striate, at first with the straight margin applied to the stipe; gills only slightly toothed, not decurrent or only so by a tooth; stipe slender, cartilaginous, usually hollow. Fig. 331.

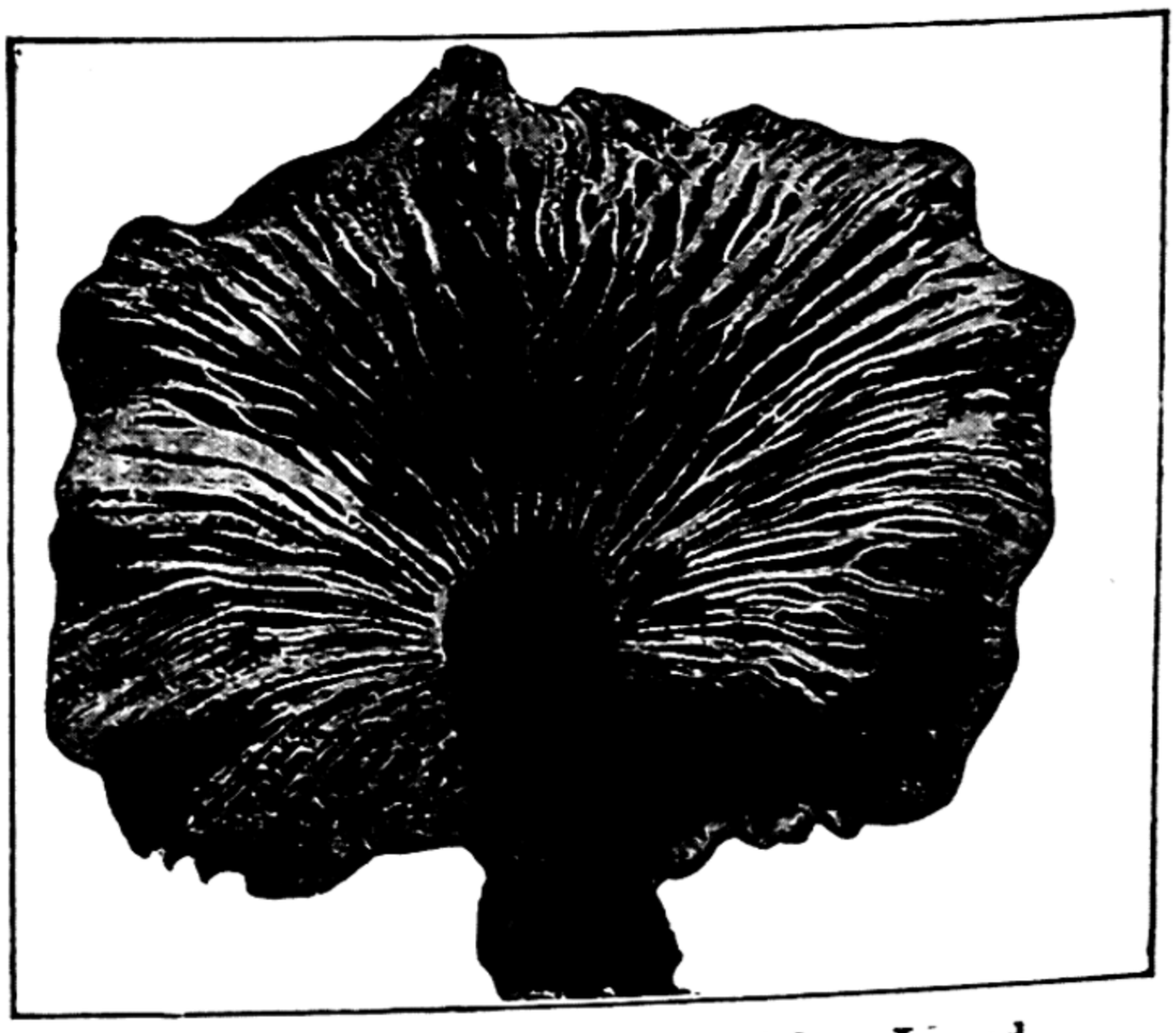


FIG. 330.—Tricholoma. After Lloyd.

A genus of some three hundred species.

M. epipterygia Scop.

Five to ten cm. high; pileus 1–2 cm. broad, viscid when moist, ovate to conic or campanulate, later more expanded, obtuse, the margin striate, sometimes minutely toothed, grayish, in age often reddish; stipe 2 mm. thick, flexuous or straight with soft hairs at the base; gills decurrent by a small tooth, varying in color from whitish through gray to a tinge of blue or red.

Usually a saprophyte, but injurious to various kinds of trees. Widely distributed in the North temperate zone.

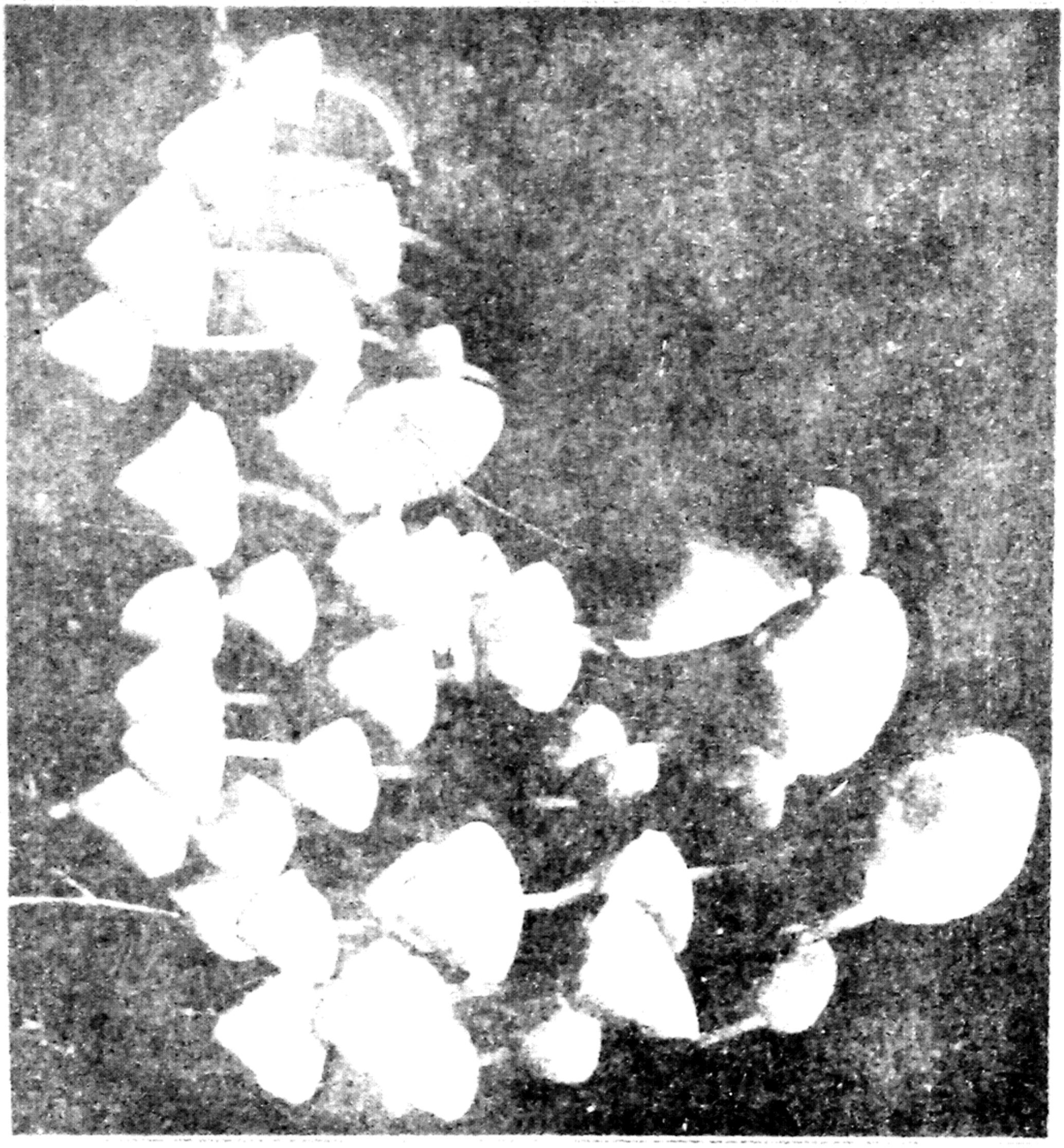


FIG. 331.—Mycena galericulata. After Clements.

Phallales (p. 395)

Mycelium rhizomorphic; sporophore with a fertile portion, the gleba, which contains a series of labyrinthine spore chambers, these lined by a hymenium of closely approximated basidia, the supporting tissue parenchymatous, spongy and elastic in texture, forming a receptacle which varies in size and form in the different genera. Except in Rhizogaster the young sporophore is volvate, and at the bursting of the volva immediately assumes its mature size and form.

An order of less than fifty species of interesting, yet from their foul odor most disagreeable fungi. At present they are regarded as mainly saprophytes.

Key to Families of Phallales

Receptacle stipitate, tubular or cylindric, capitate, with the gleba external	1. **Phallaceæ,** p. 462.
Receptacle latticed or irregularly branched, sessile or stalked; gleba enclosed by the receptacle	2. **Clathraceæ,** p. 463.

Phallaceæ

Key to Genera of Phallaceæ

Gleba borne directly on the upper portion of the stem; no special pileus	
Gleba smooth, even	1. **Mutinus.**
Gleba papillate or uneven	2. **Jansia.**
Gleba covered by a rudimentary network	3. **Floccomutinus.**
Gleba borne on the outer surface of a special pileus	
Pileus even, rugose, or reticulate	
Veil poorly developed or none	4. **Phallus,** p. 463.
Veil well developed	
Surface of the pileus regularly reticulate	5. **Dictyophora,** p. 463.
Surface of the pileus irregularly folded and convoluted	6. **Clautriavia.**
Pileus lamellate	7. **Itajahya.**

Phallus Linnæus (p. 462)

Stipe cylindric, even, bearing at the apex a smooth, rugose, or reticulate pileus.

Less than ten species are known. The following are of economic importance.

P. impudicus L.

This is one of the most widely distributed species of the genus, but not so common in America as in Europe. It is reported [110] as the cause of a root disease of the grape in Hungary.



FIG. 332.—Phallus impudicus. After Lloyd.

P. rubicundus Bosc.

Cobb [111] has described a disease of sugar cane as due to Ithyphallus coralloides. Lloyd,[112] however, refers the causal fungus to the present species, since he considers that all the red forms of "Phallus" constitute a single species.

Dictyophora Desvaux (p. 462)

A species of this genus is suspected by Cobb [113] as one of the causal fungi in a root disease of sugar cane in Hawaii.

Clathraceæ (p. 462)

The receptacle consists of a series of arms which are either spreading, erect, or latticed.

KEY TO GENERA OF **Clathraceæ**

Receptacle of free arms, or lobes at the summit of the stipe
- Stipe columnar, arms free. . . . . 1. **Lysurus.**
- Stipe enlarged upwards
  - Limb of the receptacle with suberect lobes. . . . . 2. **Anthurus.**
  - Limb of the receptacle with radiating lobes. . . . . 3. **Aserœ.**

Receptacle of simple, erect, columns, apically united and fertile only on their inner side
- Sessile. . . . . 4. **Laternea,** p. 464.
- Stalked. . . . . 5. **Pseudocolus.**

Receptacle clathrate or latticed
Sessile. . . . . 6. **Clathrus.**
Stalked
Receptacle a simple net
Stipe simple. . . . . 7. **Simblum.**
Borne on a series of columns which are united basally into a hollow tube. . . . . 8. **Colus.**
Receptacle with the network covered with knot-like projections. . . . . 9. **Klachbrennera.**

Laternea Turpin (p. 463)



FIG. 333.—Laternea columnata. After Lloyd.

Receptacle sessile, of upright, convergent columns, apically united and fertile only on the inner surface.

L. columnata (Bosc.) Ness. is recorded by Cobb [113] as one of the fungi of the root disease of sugar cane in Hawaii. The species is rather common in the Southern United States, South America, the West Indies and Hawaii.

Lycoperdales (p. 395)

Mycelium arachnoid to rhizomorphic; sporophores from the first appearing as small balls which enlarge to maturity, gleba internal at maturity, becoming a powdery spore-mass; base of the sporophore sterile; peridium double or single, parenchymatous, separating into flakes or breaking regularly; fertile hyphæ, persistent in the spore mass as a capillitium which is usually attached to the columella.

A single family **Lycoperdaceæ** with species which are usually saprophytes.

KEY TO GENERA OF **Lycoperdaceæ**

Outer peridium fragile, more or less deciduous, often warty, spiny or scaly
Capillitium of an even thickness, not branched

Sporophore with a pronounced sterile persistent base. . . . . 1. **Lycoperdon,** p. 465.
Sporophore without a pronounced sterile base
  Inner peridium opening irregularly. . 2. **Globaria.**
  Inner peridium opening by a basal pore, the outer peridium breaking equatorially and the upper half with the attached inner peridium forcefully ejected. . . . . 3. **Catastoma.**
Capillitium free, short-branched with pointed ends
  Sporophore with a pronounced persistent sterile base. . . . . 4. **Bovistella.**
  Sporophore without a pronounced sterile base
    Inner peridium papery, opening by an apical mouth. . . . . 5. **Bovista.**
    Inner peridium thick, breaking irregularly, capillitium spiny. . . 6. **Mycenastrum.**
Outer peridium splitting into star-like reflexed, persistent segments
  Inner peridium opening by a single mouth 7. **Geaster.**
  Inner peridium opening by several mouths 8. **Myriostoma.**

Lycoperdon Tournefort

Sessile, with a pronounced sterile base; peridium thin, opening regularly by an apical perforation, smooth, warty or spiny; spore-mass and capillitium filling the interior of the sporophore with echinulate spores and even, simple hyphæ.

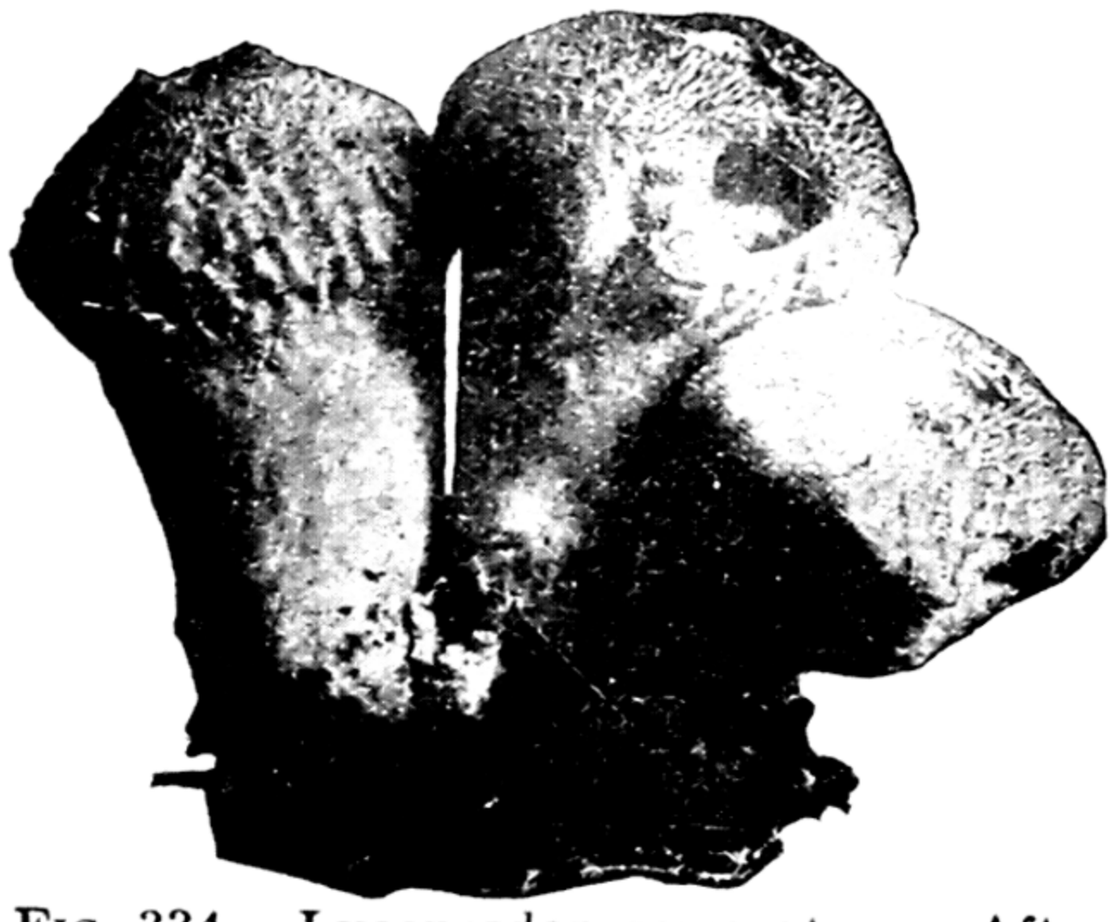


FIG. 334.—Lycoperdon gemmatum. After Lloyd.

L. gemmatum Bat. is reported by Cavara [114] on fir trees in Italy, sending its rhizomorphic mycelial strands through cambium and bark causing the destruction of both.

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FUNGI IMPERFECTI (p. 64)

In the preceding pages it has been repeatedly evident that one species of fungus may have two, even several different types of spores; in the Erysiphales the perithecial form and the conidial; in the Peronosporales oöspores and conidia; in the Sphæriales the ascigerous form and several conidial forms; in the Basidiomycetes the basidial form and various conidial forms; in the Uredinales spring and summer stages and teliospores. In comparatively few instances among the many thousand species of fungi are all of the different spore forms belonging to the species known to man. In very many cases the lower or conidial forms are known without any higher spore form (ascigerous, basidial, or sexual form), being known to be genetically connected with them, though it seems very probable, reasoning by analogy, that these conidial forms really constitute part of the life cycle of some fungus which embraces also a higher form of spore. It is probable, indeed certain, that some of these conidial forms at present possess also higher, as yet unknown, forms of fructification. It is likewise probable that in many cases the conidial form, though it does not now possess any higher spore form, did in its not remote phylogeny possess such forms; indeed that all of them are phylogenetically related to fungi which produced one of the higher types of spores.

In some cases even in the absence of the higher spore it is possible to refer the fungus to its proper order as for example is the case with the conidial forms of the Peronosporales, the summer or spring forms of the Uredinales, or the Oöspora forms of the Erysiphales.

Regarding many thousands of other conidial forms such reference is impossible or hazardous, since from the conidial form the form of the higher spore can be inferred with only a small degree of accuracy or not at all. For example, the conidial form known as Glœosporium in the higher form of some of its species proves to be a Glomerella, in other cases a Pseudopeziza; some Fusariums prove to belong to the life cycle of Nectria, others to that of Neocosmospora, etc.

In plant pathology and in systematic mycology it becomes necessary to classify, for convenience of reference and designation, these multitudinous conidial forms of which the higher spore form is as yet unknown, which may exist now or which may have existed only in the more or less remote past. From analogy it is probable that most of them pertain to the Ascomycetes, though a few may find place among other classes.

This whole group of forms, which is characterized chiefly by the imperfection of our knowledge of them, is classed together under the name **Fungi Imperfecti.**

The Fungi Imperfecti are in a temporary way divided into orders, families, genera and species as are other fungi, with full recognition of the fact that future research will result in many cases in the disclosure of higher spore forms and the consequent removal of species to their proper place in the general scheme of classification.

Recognizing the tentative nature of the genera in the Fungi Imperfecti these are spoken of as "form-genera."

Pathologically, the Fungi Imperfecti are of high importance, often occurring on leaves, stems, fruit, wood, bark, etc., as active parasites, though very many are also saprophytes. Upon leaves they are particularly common causing diseased areas known as "leaf spots."

The Fungi Imperfecti display three principal types of fructification, **pycnidia, acervuli** and **hyphæ.**

Pycnidia are more or less spherical, hollow sporocarps on the inside of which conidia are borne on stalks (**conidiophores**) arising from the base or base and sides. Figs. 349, 354. The pycnidium may be of various colors though it is most commonly black or dark; it may be superficial or imbedded, and with or without a beak (**rostrum**). The opening for the escape of the spores (**ostiole**) may be narrow, or wanting or it may be very large, round, irregular, etc. The walls vary from extremely delicate to very thick, smooth or variously provided with hairs, spines, etc.

As need arises, it is common to speak of micro-pycnidia, and macro-pycnidia. Pycnidia with very small spores are sometimes called spermogonia especially if the spores do not germinate, a custom to be deprecated.

The **acervulus** may be regarded as a pycnidium without its wall.

It consists of a close bed of short conidiophores. Figs. 371, 379. Acervuli may be small or large, subepidermal, subcortical or superficial and may or may not be provided with hairs (**setæ**) Fig. 370, of various kinds. An acervulus with a well marked basal stroma is known as a **sporodochium.** Fig. 435. If the sporodochium stalk is markedly developed the structure becomes a **coremium.** It is sometimes quite difficult to distinguish between a pycnidium with an extremely large ostiole, or one with a very thin wall, and the acervulus. For such purposes thin longitudinal sections are most useful.

Hyphæ are conidiophores which grow free for some distance above their supporting substratum and in more loose form than in the acervuli, so that the terminal parts at least stand out as separate threads, Figs. 383, 384, 396, 410.

The hyphæ may be simple and short, or long and much branched. When the hyphæ are very short and closely crowded to form a sporogenous cushion the condition of an acervulus is approached and confusion arises.

The **conidia** borne in the pycnidia, acervuli or on the hyphæ are of as various forms and types as is well conceivable and are made the chief basis for subdivision of orders into form-genera. They may be simple or compound, of almost any color, and may be borne in bisipetal succession in chains, or solitary, or in groups at the apices of the conidiophores.

The following scheme of Saccardo presents the confessedly artificial groups into which conidia may for convenience be divided.

Scheme of Spore Sections.

Amerosporæ: spores 1-celled, not stellate, spiral or filiform.
  Hyalosporæ: spores hyaline or clear, globose to oblong, continuous.
  Phæosporæ: spores dark, yellow to black, globose to oblong, continuous.
Didymosporæ: spores, 2-celled.
  Hyalodidymæ: spores hyaline, 2-celled.
  Phæodidymæ: spores dark, 2-celled.
Phragmosporæ: spores 3 to many-celled by cross septa.
  Hyalophragmiæ: spores hyaline, 3 to many-celled.
  Phæophragmiæ: spores dark, 3 to many-celled.

Dictyosporæ: spores septate, both crosswise and lengthwise, i. e., muriform.

Hyalodictyæ: spores hyaline, muriform.

Phæodictyæ: spores dark, muriform.

Scolecosporæ: spores needle-shaped to filiform, continuous or septate.

Helicosporæ: spores spirally twisted, hyaline or dark, continuous or septate.

Staurosporæ: spores stellate or radiate, hyaline or dark, continuous or septate.

The mode of bearing spores and the color of the fungus both of which it is seen are made the basis of classification have been shown by Stevens and Hall [1] and others [2] to depend largely on environment, while the septation of the spores, also a fundamental character in present classification, depends often on the age of the spores or on other factors. Many spores are unicellular until germination begins but then become typically 2-celled; e. g., Glœosporium. Such conditions have led to much inaccuracy in description and doubtless to undue multiplication of form-species.

It has been quite customary, probably to some extent excusably so, to describe as new a form-species when no form-species previously described for the same host or its near botanical kin could be regarded as identical with it. Thus a Septoria found on Vitis would ordinarily be regarded as new unless some of the Septorias already described on some of the Vitaceæ seemed to be the same, even though indistinguishable from dozens of Septorias on other families of plants. This course has led to enormous multiplication of so-called species in these form-genera giving rise to such form-genera as Septoria, Cercospora, and Phyllosticta with species numbering more than 900, 500, 800, respectively.

The condition is much as is depicted by Cobb:[3] "Is a fungus species newly found on a peach? Call it new and name it pruni. Same genus on the grape—name it ampelinum. On the apple? New, call it mali. On banana? Christen it musæ. What next? Sparrow in a pear tree, Passer pyri?"

Many of the form-genera are purely artificial—not at all well founded, e. g., Phoma is separated from Phyllosticta only by the supposed inability of the latter to grow on structures other than

leaves, a distinction which has been shown to be quite untenable.[4] It is evident that much careful study by cultures and cross inoculations is needed to reveal the true status in these Fungi.

Since the conception of species is here most loose the form species given below must be regarded as purely tentative. The names are to serve merely as handles for convenience in treating of the various parasites and in only comparatively few instances do they signify that they are really species. In many cases forms appearing under two or more names may prove eventually to be identical while in other cases forms may need to be subdivided.

Key to Orders of **Fungi Imperfecti**

Conidia produced in pycnidia.	1. **Sphæropsidales,** p. 479.
Conidia not in pycnidia	
Hyphæ innate within the matrix.	2. **Melanconiales,** p. 537.
Hyphæ somewhat superficial, often floccose	3. **Moniliales,** p. 564.
Conidia or other special reproductive cells unknown.	4. **Mycelia sterilia,** p. 659.

The Sphæropsidales

Conidia in pycnidia which open by pores or slits, superficially resembling the perithecia of the Ascomycetes.

The Sphæropsidales are preëminently leaf-spotting fungi though many of them grow on fruit or stems causing blight, rot, cankers etc. The vast majority are saprophytes or parasitic on tissues of weak vitality, but not a few are active parasites.

Key to Families of **Sphæropsidales**

Pycnidia globose, conic, or lenticular	
Pycnidia membranous, carbonous or coriaceous, black.	1. **Sphærioidaceæ,** p. 480.
Pycnidia fleshy or waxy, light colored.	2. **Nectrioidaceæ,** p. 526.
Pycnidia more or less dimidiate, irregular or shield-shaped, black.	3. **Leptostromataceæ,** p. 528.
Pycnidia cup-shaped or patelliform, black.	4. **Excipulaceæ,** p. 533.

The Sphærioidaceæ (p. 479)

Pycnidia globose, ovate, or clavate, leathery to carbonous, black or dark brown, opening by a pore, superficial, erumpent or covered; stroma present or absent; conidia variable in form, color, and division.

The family is subdivided according to its spores as indicated below.

Key to Sections of Sphærioidaceæ

Conidia globose to elongate, straight or falcate, 1 to many-celled	
Conidia 1-celled, globose, ovate or elongate	I. **Amerosporæ.**
Conidia hyaline	1. **Hyalosporæ,** p. 480.
Conidia colored	2. **Phæosporæ,** p. 500.
Conidia 2-celled, ovate to elongate	II. **Didymosporæ.**
Conidia hyaline	3. **Hyalodidymæ,** p. 505.
Conidia colored	4. **Phæodidymæ,** p. 509.
Conidia 3 to many-celled, by transverse septa, elongate	III. **Phragmosporæ.**
Conidia hyaline	5. **Hyalophragmiæ,** p. 513.
Conidia colored	6. **Phæophragmiæ,** p. 514.
Conidia muriform, ovate to elongate	IV. **Dictyosporæ.**
Conidia hyaline	7. **Hyalodictyæ.**
Conidia colored	8. **Phæodictyæ,** p. 516.
Conidia filiform, 1 to many-celled, hyaline or colored	V. 9. **Scolecosporæ,** p. 517.
Conidia cylindric, spirally coiled, 1 to many-celled, hyaline or colored	VI. 10. **Helicosporæ.**
Conidia stellate, 1 to many-celled, hyaline colored	VII. 11. **Staurosporæ.**

Sphærioidaceæ–Hyalosporæ

Spores hyaline, 1-celled, spherical, elliptical or long.

Key to Genera of Sphærioidaceæ-Hyalosporæ

Stroma none; pycnidia separate.

Pycnidia smooth

Conidia borne singly

Conidia unappendaged
Pycnidia free in the substratum; subiculum none
Pycnidia not beaked, opening by a pore, or irregularly
Not growing on other fungi
Pycnidia opening by a regular pore
Pycnidia more or less sunken in the substratum
Pycnidia globose, etc. not spindle-shaped
Pycnidia borne on dark colored spots, or on wood, globose
Conidiophores simple or nearly so
Pycnidia rather large
Pycnidia at first covered, then erumpent
Spores under 15 μ
On leaves only. . . . . 1. **Phyllosticta,** p. 483.
Not on leaves. . . . . 2. **Phoma,** p. 490.
Spores over 15 μ. . . . . 3. **Macrophoma,** p. 493.
Pycnidia from the first superficial . . . . . 4. **Aposphæria,** p. 494.
Pycnidia very small, closely aggregated on dark spots on the leaf. . . . . 5. **Asterostomella.**
Conidiophores branched. . . . . 6. **Dendrophoma,** p. 494.
Pycnidia scattered, superficial, circular, conidia elongate or cylindric. . . . . 7. **Crocicreas.**
Pycnidia globose; conidiophores circinate. . . . . 8. **Pyrenotrichum.**
Pycnidia horizontal, free, cylindric. . . . . 9. **Glutinium.**
Pycnidia opening irregularly, or operculate
Spores globose. . . . . 10. **Mycogala.**
Spores elongate or ellipsoid
Pycnidia operculate. . . . . 11. **Piptostomum.**
Pycnidia opening irregularly

Spores pointed. . . . . 12. **Sclerotiopsis.**
Spores blunt. . . . . 13. **Plenodomus.**
On Erysiphaceæ. . . . . 14. **Cicinnobolus,** p. 494.
Pycnidia beaked. . . . . 15. **Sphæronema,** p. 494.
Pycnidia on a subiculum
Conidia ovate or elongate
Subiculum of simple hyphæ
Pycnidia free. . . . . 16. **Byssocystis.**
Pycnidia sunken in the subiculum. . 17. **Chætophoma,** p. 495.
Subiculum radiate. . . . . 18. **Asteroma,** p. 496.
Conidia Y-shaped. . . . . 19. **Ypsilonia.**
Conidia appendaged. . . . . 20. **Neottiospora.**
Conidia in chains
Conidial chains separate and simple . . . 21. **Sircoccus.**
Conidial chains connected, often forming a net. . . . . 22. **Pecia.**
Pycnidia appendaged or hairy
Appendages simple
Pycnidia with short simple tubercles; conidia irregular in outline. . . . . 23. **Muricularia.**
Pycnidia with long bristles; conidia regular
Bristles septate, usually covering the entire pycnidium, conidia cylindric fusoid, usually curved. . . . . 24. **Vermicularia,** p. 496.
Bristles usually only at the apex; conidia ovate, elongate or cylindric, straight. . . . . 25. **Pyrenochæta,** p. 497.
Appendages stellate at the apex. . . . . 26. **Staurochæta.**
Pycnidia stromatic, superficial or sunken
Pycnidia single on the stroma
Pycnidia with a single chamber
Conidiophores filiform. . . . . 27. **Phomopsis,** p. 493.
Conidiophores indistinct or absent
Stroma indistinct. . . . . 28. **Plenodomus.**
Stroma rather well developed. . . . . 29. **Sclerophoma.**
Pycnidia typically with more than one chamber. . . . . 12. **Sclerotiopsis.**
Pycnidia with well developed stroma, free or buried
Pycnidia with separate mouths

Pycnidia single on the stroma. . . . . 30. **Dothiopsis.**
Pycnidia several on each stroma
Conidia separate from each other
Pycnidia scattered irregularly
Stroma sharply defined, globose, etc.
Pycnidial chambers appearing as enlargements from without . . . 31. **Anthracoderma.**
Pycnidial chambers not as above
Stroma valsoid
Conidia straight
Conidia large, fusiform. . . . . 32. **Fusicoccum,** p. 498.
Conidia small, ovate, clavate or cylindric
Conidia ovate or clavate, very small. . . . . 33. **Cytosporella,** p. 498.
Conidia larger, ovate, or elongate
Pycnidia superficial or subsuperficial
Conidiophores simple. . . . . 34. **Dothiorella,** p. 499.
Conidiophores branched. . . . 35. **Dothiorellina.**
Pycnidia deep seated. . . . . 36. **Rabenhorstia.**
Conidia allantoid. . . . . 37. **Cytospora,** p. 499.
Stroma pulvinate. . . . . 38. **Fuckelia,** p. 500.
Stroma indefinite, on black spots on the host plant. . . . . 39. **Placosphæria.**
Pycnidia regularly arranged on the stroma around a sterile center. . . 40. **Lamyella.**
Conidia adhering basally in fours. . . . . 41. **Gamosporella.**
Pycnidia on each stroma with a common ostiole
Stroma globose or flask-shaped; conidia curved. . . . . 42. **Torsellia.**
Stroma conic-truncate, conidia elongate cylindric, straight. . . . . 43. **Ceuthospora,** p. 500.
Stroma thin, effuse; conidia curved to allantoid. . . . . 44. **Plagiorhabdus,** p. 500.

Phyllosticta Persoon (p. 481)

Pycnidia immersed, erumpent or with the beak piercing the

epidermis, lenticular to globose, thin membranous, opening by a pore; conidia small, ovate to elongate, continuous, hyaline or green; conidiophore short or almost obsolete. On leaves.

In part = Guignardia, Valsonectria, Mycosphærella.

The genus is a very large one of some eight hundred forms, few of which have been adequately studied. It differs from Phoma only in that it is foliicolous while Phoma is caulicolous, a distinction which

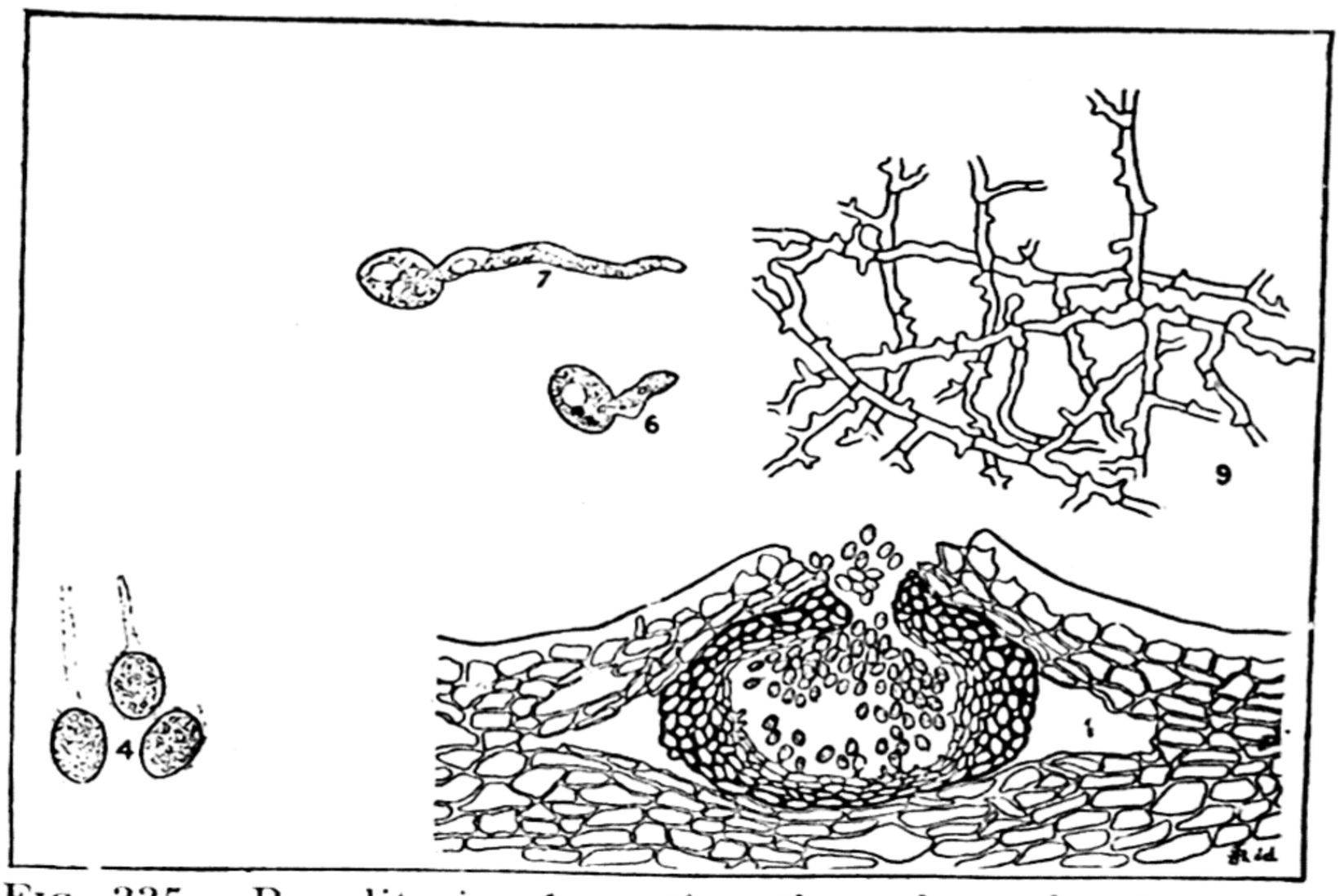


FIG. 335.—P. solitaria. 1, section through apple; 4, spores from apple blotch showing appendages; 6–7, germinating spores; 9, mycelium from corn-meal cultures. After Scott and Rorer.

is not consistently maintained and which is untenable for generic limitation (see p. 478).

The fungus produces leaf spots by killing or weakening the leaf tissue with its mycelium. The spots are circular or subcircular, unless rendered angular by obstruction by veins, and the pycnidia may usually be seen with a lens in old spots unless the color of the leaf forbids. Similar effects follow on fruits.

P. ampelopsidis E. & M. on Ampelopsis is probably identical with **P. labruscæ** = Guignardia bidwellii. See p. 238.

P. bellunensis Mart. on elm = Mycosphærella ulmi. See p. 249.

P. brassicæ (Carr.) West on cabbage, etc. = Mycosphærella brassiæcola.[5] See p. 249.

P. labruscæ Thüm. on the grape = Guignardia bidwellii. See p. 238

P. tabifica Prill is perhaps identical with Mycosphærella tabifica, though Potebnia[6] questions this. See p. 247.

P. maculiformis (Pers.) Sacc. on chestnut = Mycosphærella maculiformis. See p. 249.

P. solitaria E. & E.[7, 8]

Perithecia minute, immersed, the ostiole only erumpent; conidia broadly elliptic, 8–10 x 5–6 μ, surrounded by a mucilaginous sheath.

It is the cause of apple fruit blotch and of cankers and leaf spots. On the fruit it was first reported by Clinton[9] in 1902. The fruit spots show a characteristic fringed appearance owing to the unequal advance of the mycelium which is limited to the outermost fruit cells. In the fruit the pycnidia develop subepidermally.

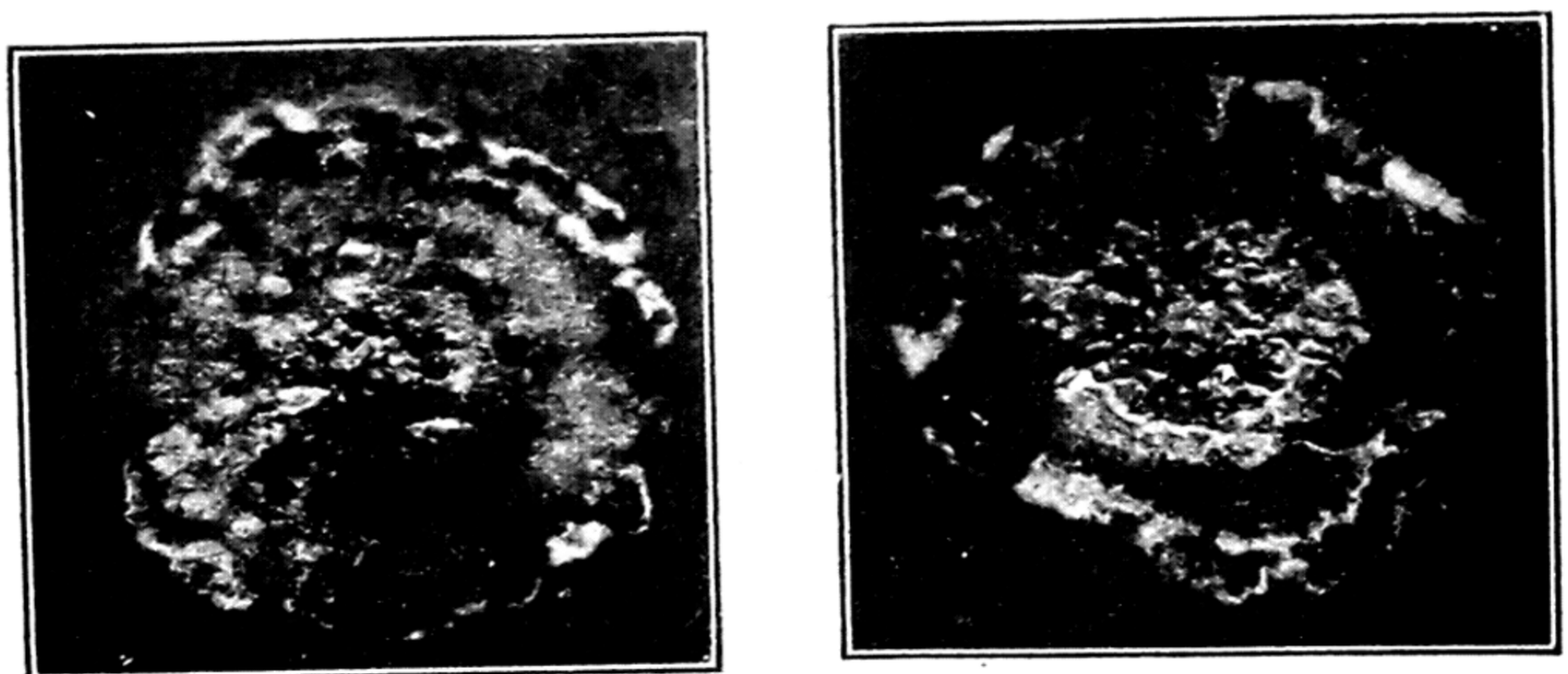


FIG. 336.—P. solitaria. 1-month-old colony on apple agar. After Scott and Rorer.

The fungus was grown in pure culture and its identity on twig, leaf and fruit was shown by cross inoculation.

P. persicæ Sacc. is common on peach leaves.

P. piricola Sacc. & Speg. is found on apple and pear.

P. limitata Pk.[10] is reported as the cause of an apple leaf spot.

Spots round minute, 2–6 mm., brown or reddish; pycnidia epiphyllous, black, few, punctiform; spores ellipsoid, 7–8 x 4 μ. **P. mali** P. & D. occurs on apple and pear.

P. pirina Sacc.[11]

Spots variable; pycnidia epiphyllous, punctiform, lenticular, 100–130 μ, context loosely cellular, brown; conidia ovoid to ellipsoid, 4–5 x 2–2.5 μ.

This was long regarded as the chief factor causing the common leaf spot on the apple and pear. Recent work throws doubt on this.

P. circumscissa Cke.

Amphigenous; spots orbicular, reddish-brown, at length deciduous; pycnidia scattered, minute; conidia elliptic, 8 x 2 μ.

Spots and shot holes are formed on drupaceous hosts.

P. prunicola Sacc.[12]

Spots subcircular, epiphyllous, sordid-brownish or ochraceous, margin subconcolorous; pycnidia scattered, punctiform; conidia ovoid to ellipsoid, 5 x 3 μ.

It is found on Prunus, causing leaf spots in Europe, America and Australia. Scurf is also produced on apple bark.

P. armenicola Far. is associated with an apricot fruit disease.

P. grossulariæ Sacc. grows on Ribes grossularia.

P. fragaricola D. & R. is widespread in Europe on the strawberry.

P. vitis Sacc. and **P. succedanea** (Pass.) All. are found on grape in Europe.

P. vialæ R. & G. also parasitizes the grape.

P. bizzozeriana Mass. in Hungary produces a grape disease superficially resembling black rot.[13]

P. putrefaciens Sh. occurs on cranberry.

P. oleæ Pet. and **P. insulata** Mont. cause leaf spots on the olive.

P. cannabinis Kirch forms spots on hemp leaves;

P. humuli Sacc. & Speg. on the hop.

P. bataticola E. & M. Pycnidia scattered, minute, black; spots small rounded, whitish with a purple margin; conidia ellipsoid, 5 x 2μ. Leaf spots are produced on the sweet potato.

P. nicotiana E. & E.

Spots brown, reddish, zonate; pycnidia 200 μ, black; conidia 3.5–5 x 1.5 μ. It causes leaf spots of tobacco;[14]

P. tabaci Pass. also occurs on Nicotiana.

P. medicaginis (Fcl.) Sacc. occurs on alfalfa; [15]

P. japonica Miy. and **P. miuria** Miy. parasitize rice. [16]

P. betæ Oud.

Spots grayish-ochre, large and irregular; pycnidia epiphyllous, minute, densely clustered, brownish, subimmersed; conidia elliptic, 5–6 x 3 μ.

It is mentioned by Stewart [17] as the cause of leaf spots of beets.

P. malkoffi Bub. causes cotton leaf spots in Bulgaria.

P. coffeicola Del. and **P. comœnsis** Del. are on coffee;

P. cinnamoni Del. on cinnamon leaves;

P. hevea Zimm. on Para rubber.

P. hortorum Speg.[18, 19]

Spots circular, indefinite, fulvous, gray in the center, amphigenous, at last falling away; pycnidia in the center of the spot, minute, 80–90 μ, globose-lenticular, thin, membranous, dull fusco-olivaceous; conidia elliptic to ovoid, rounded at the ends, 4–6 x 2–2.5 μ.

It produces spots on leaves and fruit of egg plant in Europe and America.

P. chenopodii Sacc.[20]

Spots irregular, scattered or confluent, ochraceous, fuscous margined; pycnidia lenticular, punctiform, 50 μ; conida oblong-elliptic, 5 x 3 μ. A leaf spot is produced on spinach.

P. apii Hals.[18] forms brown spots on leaves of celery; pycnidia punctiform, black; conidia elliptic to ovate oblong.

P. phaseolina Sacc.

Spots irregularly scattered, subcircular, 2–10 mm., deep rusty brown, becoming lighter in center and darker margined; pycnidia scattered, 70–90 μ; conidia ovoid oblong, 4–6 x 2–2.5 μ.

It causes spotting of bean and cowpea.[453]

P. cucurbitacearum Sacc.

Spots epiphyllous or amphigenous, sordid, whitish; pycnida punctiform, 80–100 μ, lenticular; conidia oblong, 5–6 x 2½ μ, curved.

On muskmelon, cucumbers and other cucurbs, spotting the leaves.[14, 21–23]

P. citrullina Chester[76] is also reported on melons,[144]

P. maculicola Hals.[21] produces spots in Dracæna and related plants.

P. hedericola Dur. & M. and **P. hederacea** (Arc.) All. cause spots on Hedera leaves,[24, 441]

P. rosæ Desm. and **P. argillaceæ** Bres. occur on roses.

P. rosarum Pass. causes a black spot on roses in New South Wales.

P. althæina Sacc.[18]

Spots irregular, with a dark brown margin; pycnidia few, lenticular, 90 μ, ochraceous; conidia ovate-oblong, 6–7 x 3–4 μ.

On hollyhock in Italy, France and America.

P. idæcola Cke. forms spots on cultivated species of Sida and Hibiscus.

P. dianthi West. grows on Dianthus leaves.

P. primulæcola Desm. occurs on Primula leaves.[26]

Amphigenous; spots large, white, light margined; pycnidia epiphyllous, numerous, prominent, globose, black; conidia subglobose.

P. violæ Desm.[27, 28]

Amphigenous, spots white, round; pycnidia numerous, minute, brown; spores minute, subcylindric, 10 μ long.

Common, causing leaf spots on pansy and violet.

P. hydrangeæ E. & E.[18]

Spots 1.5–1 cm. or more, rusty brown, margin narrow, raised, at first shaded with purple; pycnidia epiphyllous, lenticular, 100-115 μ; conidia oblong, 10–12 x 2.5–3.5 μ.

On Hydrangea causing leaf spots.

P. syringæ West. is common on lilac.

P. halstedii E. & E.

Amphigenous, spots roundish, reddish-brown, ¼–1¼ cm. concentrically zonate, pycnidia few, lenticular, 100–150 μ, immersed; conidia broadly fusoid-oblong, 15–20 x 5–7 μ. Causing a leaf spot of the lilac.

P. cruenta (Fr.) Kick.

Spots subcircular, reddish, becoming paler in the center; pycnidia gregarious or scattered, globose-lenticular, dark olivaceous; conidia ovate-oblong, 14–16 x 5.5–6.5 μ; conidiophores, cylindric, 10–12 x 4 μ.

It causes leaf spots of cultivated Solomon's Seal.

P. cyclaminis Brun. occurs on cyclamen;

P. digitalis Bell on digitalis.

P. chrysanthemi E. & D.[26]

Spots purplish-brown, pycnidia 80–100 μ; conidia 4–5 x 2.5–3 μ.

It causes leaf spots on cultivated chrysanthemums.

P. leucanthemi Speg. is occasionally found in spots of chrysanthemum leaves.

P. richardiæ Hals.[26] is common as a leaf spotter of the calla lily but has not been satisfactorily described.

P. opuntiæ Sacc. & Speg. occurs on various of the Cactaceæ;

P. liliicola Sacc. on lily;

P. vincæ minoris B. & K. on Vinca minor;

P. pteridis Hals. causes blighting of cultivated Pteris; [21]
P. narcissi Aderh. of narcissus.[30]
P. cavaræ Trinch. produces white spots on leaves of Anthurium.[31]
P. dracænæ causes spots on Dracæna leaves.
P. funckia Hals. Pycnidia 75–150 μ, straw colored.
The cause of leaf spots of cultivated Funkias.[27]
P. dammaræ is found on Dammara in Italy;
P. nobilis Thüm. on Laurus.
P. ulmicola Sacc.

Spots indefinite, ochraceous, margin concolorous; pycnidia gregarious, punctiform, 70–80 μ, lenticular; conidia oblong ellipsoid, 6–3 μ. It infests elm leaves.[14]

P. acericola C. & E.[32]

Spots irregular, fuscous, brown margined; pycnidia densely scattered on the central part of the spot, subepidermal, flask-shaped, dark brown, 120 μ; conidia ovate, 8–9 x 5–6 μ.

It causes serious leaf spotting of maples throughout the United States.

P. aceris Sacc. forms small spots on maple leaves.
P. paviæ Desm.

Spots indeterminate, reddish, lighter margined; pycnidia epiphyllous, black; conidia cylindric-elliptic, 11–12 μ long. It is said to be common on Æsculus.[14]

P. sphæropsidea E. & E.[33]

Epiphyllous; spots reddish-brown, margin lighter, scattered or confluent, 1–2 cm.; pycnidia scattered, immersed, punctiform, erumpent above, subepidermal; conidia globose to broadly ellipsoid, hyaline, 12–15.5 x 8–10 μ.

It causes serious leaf spotting of chestnuts throughout the United States.

P. tiliæ Sacc. & Speg. is found on Tilia.
P. minima (B. & C.) E. is on Negundo.
P. catalpæ E. & M.

Spots, rounded, brown, 3–6 mm., often confluent; pycnidia subcuticular, small, black, scattered, 112 x 84; conidia ovate, 5–7 x 2.5–4.5 μ. It causes leaf spots on Catalpa.[34]

P. magnoliæ Sacc. causes leaf spots on Magnolia; **P. viridis** E. & K. on ash; **P. ilicina** Sacc. on the cork oak.

An unidentified species has been reported on watermelon [35] as cause of considerable injury. Halstead mentions also an undetermined species on oats.[26] Pycnidia 150–250 μ; spores 12–18 x 6–7 μ, pyriform.

Phoma (Fries) Desmaziere (p. 481)

The genus as at present recorded contains over 1200 forms. It is indistinguishable from Phyllosticta (see p. 484) except that it is caulivorous. Several species are regarded as conidial forms of Diaporthe, Mycosphærella, etc.

P. reniformis on grape = Guignardia bidwellii. See p. 238.

P. albicans Rob. & Desm. on chicory = Pleospora albicans. See p. 260.

P. betæ Fr. on beet = Mycosphærella tabifica. See p. 247.

P. bohemica Bub. & Kab. on fir tree needles = Rehmielliopsis. See p. 276.

P. ambigua (Nitz.) Sacc. on pear = Diaporthe ambigua. See p. 279.

P. sarmentella Sacc. on hop = Diaporthe sarmentella. See p. 279.

P. persicæ Sacc.

Pycnidia scattered to gregarious, globose lenticular, $^1/_6$–$^1/_5$ mm.; conidia oblong ovoid, 8–3 x 2 μ, conidiophores cylindro-conical, equal in length.

It produces constriction and death of peach twigs.[36]

P. mali S. & S.[37, 38]

Pycnidia gregarious, subcuticular, depressed, ostiole erumpent; conidia oblong-fusoid, 2–3 x 5–8 μ.

It attacks the wood of young apple trees and also causes a decay of the fruit.

P. cydoniæ Sacc.[39]

Pycnidia subgregarious, depressed, ostiole obtuse or erumpent, conidia elliptic oblong, 8–9 μ long; conidiophores short.

A form causing rot of quince fruit was provisionally referred to this species by Halsted.

P. limonis Thûm. & Boll. **P. citri** Sacc. and **P. aurantiorum** (Rab.) Sacc. occur on citrous fruits;

P. pomarum Thüm. on pomaceous fruits in Europe.

P. myxiæ Far. is associated with an apricot fruit spot.

P. omnivora McA. is described as the cause of Australian wither tip of the orange [40] while to **P. citricarpa** McA is attributed another common Australian citrous fruit disease.

P. mororum Sacc. is on Morus.

P. tuberculata McA. causes a disease of grape berries in Australia.[41]

P. lophiostomoides Sacc. is common and perhaps parasitic on cereals.

P. hennebergii Kühn produces brown spots on the glumes of wheat and leads to some injury to the grain.[42]

P. solanicola P. & D.[43] causes a disease of potato [163] stems in France.

P. solani Hals.[18]

Pycnidia innate, depressed, oblong; conidia oblong.

On egg plant causing damping-off of seedlings.

P. subcircinata E. & E.

Pycnidia black, 70–90 μ; conidia 5–6 x 2–2.5 μ.

Spots are produced on bean pods.

P. sanguinolenta Rost.[44]

Pycnidia scattered, subglobose; conidia ellipsoid, 4–6 x 1.5–3 μ; surrounded by a slime which gives the spore-mass a violet-red color.

As the cause of a rot of carrot roots it has been reported in New Jersey.

P. oleraceæ Sacc.[45–48]

Pycnidia scattered, globose depressed, papillate, sunken in the tissues, ¼–½ mm.; conidia oblong, subcylindric, medially constricted, apically obtuse, 5–6 x 2 μ.

Manns notes this fungus causing a serious cabbage disease in Ohio. The pycnidia are sparse on oval sunken diseased areas on the stems, and bacterial invasion follows soon in leaves, cambium and xylem. The cambium is rapidly destroyed and the plant collapses. Bos [47] and Quanjer [48] have demonstrated the pathogenicity of the fungus.

P. napobrassicæ Rost. causes rot of mangolds in Denmark; [49–51] also recently reported from Canada.[450]

P. apiicola Speg. is recorded on celery.[52]

P. brassicæ Thüm. on cabbage is probably identical with P. oleraceæ.

P. roumii Fron. is said to cause a serious cotton disease in Africa.[53]

P. batatæ E. & H.[54]

Pycnidia blackish, gregarious, immersed; conidia terete, ovoid; conidiophores slender. The cause of dry rot of sweet potatoes.

P. chrysanthemi Vogl. is found on leaves of chrysanthemum causing them to wilt.

P. malvacearum West is noted on European hollyhocks;

P. devastatrix Berk. on cultivated lobelias;

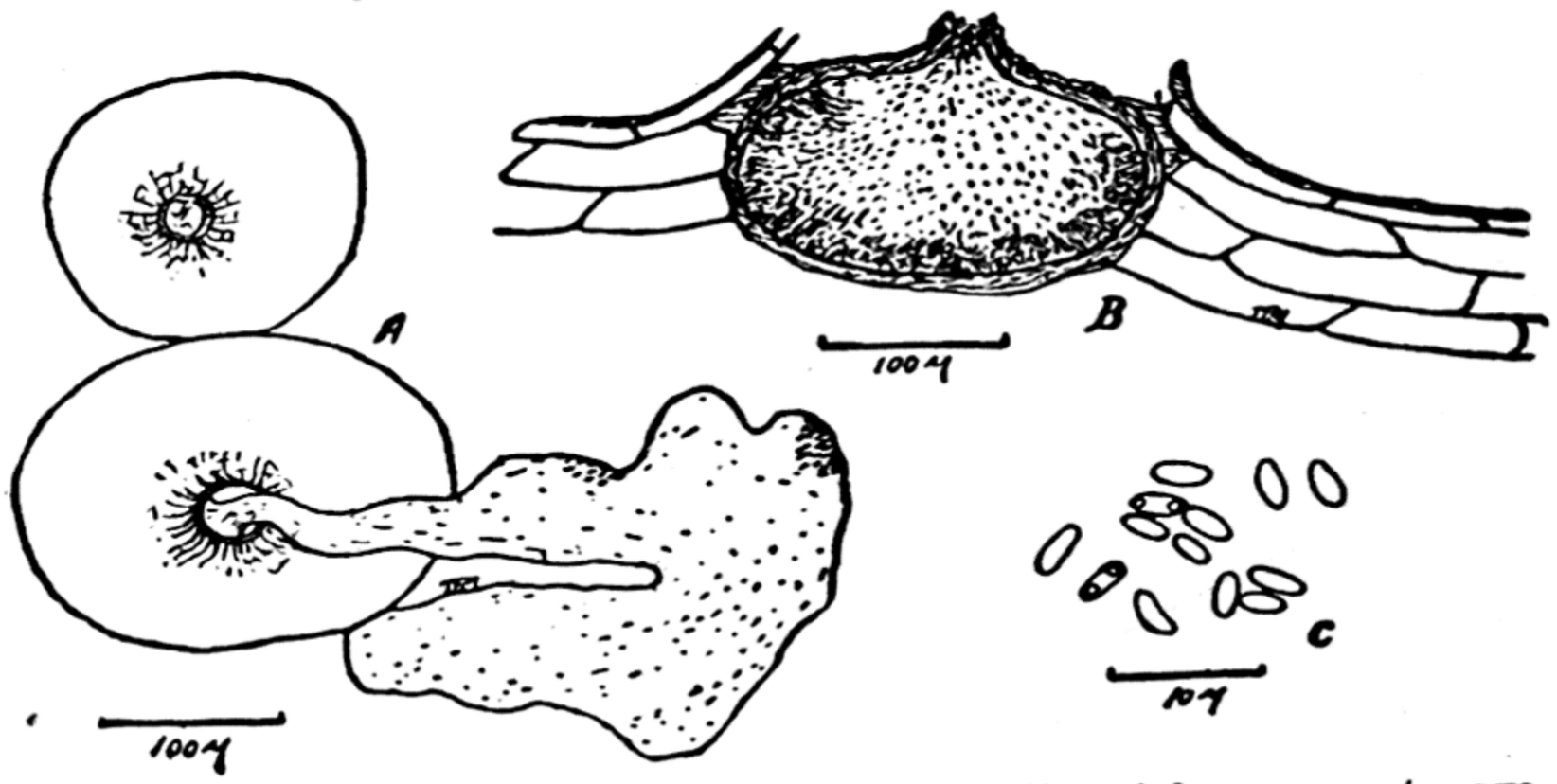


FIG. 337.—P. oleracea. *A*, showing pycnidia with spores streaming out; *B*, section; *C*, spores. After Manns.

P. dahliæ Berk. on stems and flowers of Dahlia.

P. cyclamenæ Hals. is given as the cause of Cyclamen leaf spots but without ample description.

P. oleandrina Del. is on the rose, laurel, etc.

P. pithya Sacc. seems to be parasitic on the fir causing constriction and death of twigs.

P. strobi (B. & Br.) Sacc. is prevalent on white pine in Europe.

P. strobilinum P. & C. is closely related to the above.

P. sordida Dur. & M. occurs on Carpinus.

P. ribesia Sacc. Pycnidia collected, erumpent, spores oblong-fusoid, 10 x 3½ μ, hyaline. In branches of Grossulariæ.

Several undetermined species have been reported, among them

one on snapdragon,[55] another on Clematis roots,[56] and one on apple [434]

Phomopsis Saccardo [57] (p. 482)

As in Phoma, but with hooked conidiophores. A small genus.

P. aloeapercrassæ Trinch. is reported on scapes and flowers of the aloe in Italy.

P. stewartii Pk.

Perithecia gregarious, commonly occupying grayish or brown spots, thin, subcutaneous, at length erumpent, depressed, minute, $^1/_3$–$^1/_2$ mm. broad, black; spores of two kinds, first; filiform, curved, flexuous or uncinate, hyaline, 16–25 x 1–1.5 μ, second; oblong or subfusiform, hyaline, commonly binucleate, 8–12 x 2–3 μ; sporophores slender, equal to or shorter than the spores.

The fungus with its filiform spores only was noted as a parasite on Cosmos by Halsted who referred to it as a species of Phlyctæna.[26] It has been noted in New York by Stewart,[17] and is destructive both in the greenhouse and in the open.

Macrophoma Berlese & Voglino (p. 481)

As in Phoma, but the ostiole of the pycnidium not papillate, and the pore smaller; conidia over 15 μ long; conidiophores simple, short or filiform.

About one hundred seventy-five species.

M. hennebergii (Kühn) Berl. & Vogl. causes a serious disease on wheat in Sweden.[61]

The fungus which appears in the literature as **M. curvispora** Pk. is in reality Glœosporium malicorticis, see p. 542, and that referred to as **M. malorum** is Myxosporium corticolum. See p. 546.



FIG. 338.—M. curvispora, spores. After Cordley.

M. vestita Prill. & Del. attacks cacao in Ecuador.

M. dalmatica (Thüm.) B. & V. parasitizes the olive; **M. taxi** B. & V. attacks the leaves of Taxus; **M. abietis** M. & H. is associated with a fir disease; **M. manihotis** Hem. is on cassava; **M. ligustica** Magnag on Hydrangeas; **M. helicinia** Magnag on ivy.

M. reniformis (V. & R.) Car. is reported on grapes in Algiers, Italy and Russia.

Aposphæria Berkley (p. 481)

Pycnidia globose, carbonous, with a papillate ostiole, erumpent or superficial; conidia elongate to globose; conidiophores very short or absent.

One hundred species are recognized.

An undetermined species was found by Stevens [21] in New York and New Jersey in 1892, causing diseased spots on strawberry leaves.

Dendrophoma Saccardo (p. 481)

Pycnidia superficial or subepidermal and erumpent, carbonous; ostiole papillate; conidia elongate; conidiophores branched.

A genus of some fifty species, chiefly saprophytes.



FIG. 339.—Dendrophoma; conidiophores and conidia. After Allescher.

D. marconii Cav. occurs on hemp stems; **D. convallariæ** Cav. on leaves of Convallaria majalis; **D. valsispora** Penz on living lemon leaves.

Cicinnobolus Ehrenberg is frequently met as a parasite on the mycelium of the Erysiphales.

Macrodendrophoma salicicola on Salix = Physalospora gregaria. See p. 252.

Sphæronema Fries (p. 482)

Pycnidia superficial or not, pyriform, cylindric or globose, rostrum long; conidia ovate or elongate.

Some seventy-five species, chiefly saprophytes, have been described.

S. phacidioides Desm. on clover = Pseudopeziza trifolii. See p. 148.

S. fimbriatum (E. & H.) Sacc.[54, 62]

Pycnidia globose, 100–200 μ, surrounded by septate, hyaline

hyphæ, rostrum, 20–30 μ long, apically fimbriate; conidia globose-elliptic, 5–9 μ.

The fungus grows in the sweet potato producing dark, almost black spots in the skin. The tissue below becomes olive-green. The dark mycelium is found penetrating through and between cells of the diseased area where numerous olivaceous conidia are also present. The elongated beaks of the pycnidia rise like a small forest from the surface of the potato.

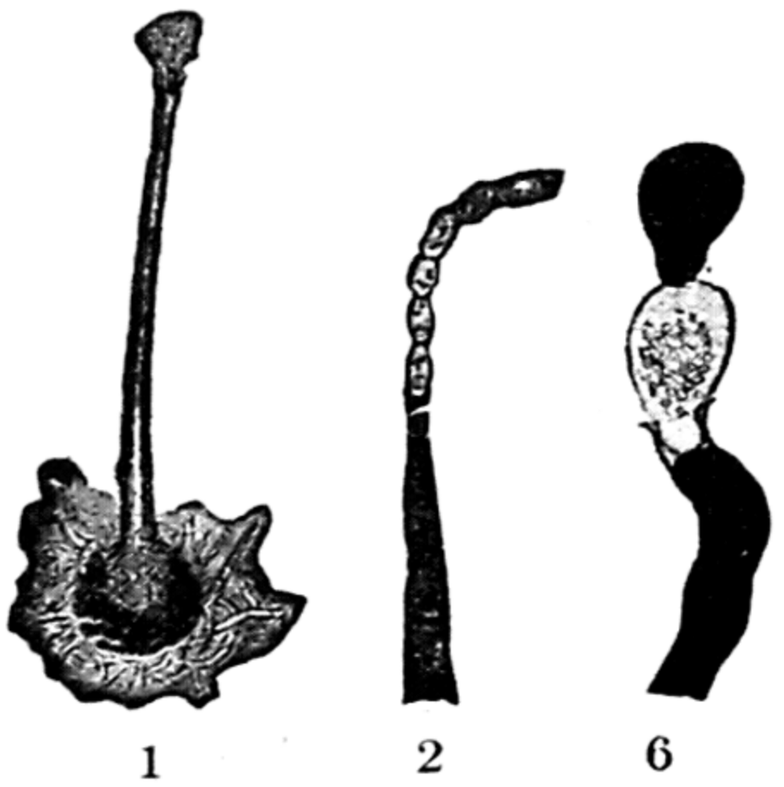


FIG. 340.—S. fimbriatum; 1, pycnidium sending forth spores; 2, hyaline conidia; 6, olive conidia. After Halsted and Fairchild.

In artificial culture the mycelium is dark, abundantly septate and with numerous oil globules. Long multiseptate conidiophores with light colored tips arise from the medium. From these hyaline conidia are produced, apparently endogenously. Fig. 340, Olivaceus, globose to elliptical, Fig. 340, conidia are formed within the medium on branches of the mycelium in much the same manner. The pycnidia develop in about nine days after inoculation and the conidia are extruded from the fimbriate mouth of the long rostrum.

Inoculations proved the pathogenicity of the organism, typical black rot appearing in about three weeks after infection.

S. adiposum Butler causes a black rot of sugar cane.[54]

S. pomarum Sh. is on cranberry.

S. spurium (Fr.) Sacc. on Prunus is often reported as Dematium prunastri.

S. oryzæ Miy. is on rice.[16]

Chætophoma Cooke (p. 482)

Pycnidia superficial, very small, on a subiculum of interwoven hyphæ; conidia ovate or elliptic, very small.

Some forty species, chiefly American.

C. glumarum Miy. parasitizes rice in Japan.[16]

Asteroma De Candolle (p. 482)

Pycnidia very small, globose, erumpent, often on a mass of hyphæ; conidia ovate or short cylindric. In part =Gnomonia. See p. 274.

About forty species chiefly parasitic.

A. padi (D. C.) Grev. on Prunus=Gnomonia padicola. See p. 275.

A. geographicum (D. C.) Desm. occurs on various species of Pomaceæ;

A. punctiforme Berk. on the rose;

A. stuhlmanni Hen. on bananas and pineapples in Africa.

A. codiæi All. is said to be a serious parasite of Codiæum.[63]

Vermicularia Fries (p. 482)

Pycnidia superficial, or erumpent, globose depressed, to globose clavate, leathery or carbonous, black, ostiolate or not, beset with rather long, stiff, septate, dark colored bristles; conidia cylindric-fusoid, often curved.

Some one hundred thirty species, chiefly saprophytes.

V. dematium (Pers.) Fr.

Pycnidia erumpent, superficial, 80–120 μ, conic, then depressed, often confluent, black, spines pale at the ends, 150–200 x 5 μ; conidia cylindric-elongate, 20 x 4–6 μ, apically rounded, curved.

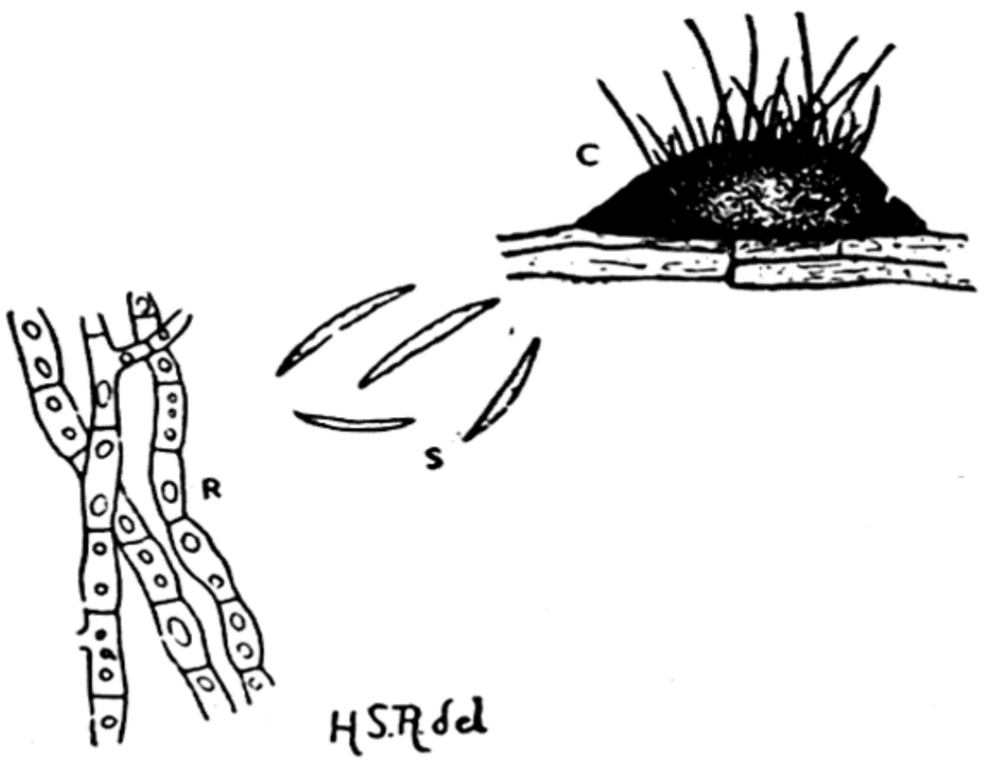


FIG. 341.—V. dematium. C, a nearly mature "perithecium;" S, spores; R, hyphæ. After Reed.

Commonly a saprophyte, this fungus occasionally causes asparagus disease.[65] In Europe it is reported as the cause of much loss to the ginseng crop. On this plant it produces a stem anthracnose. The fungus was isolated and its cultural characters studied by Reed.[64]

V. trichella Fr.

Pycnidia ovate, small, black, spines long, at the apex of the pycnidium; conidia fusoid, curved, pointed, 16–25 x 4–5 μ.

On living parts of many fruit hosts, as well as ivy and other woody plants.[21]

V. melicæ Fcl. grows on Melica;

V. microchæta Pass. on camellia.

V. circinans Berk.[66, 67]

Spots orbicular; pycnidia arranged concentrically, small, setæ long; conidia oblong, curved, obtuse.

On onions the fungus appears as small black dots on the scales. These later become encircled by rings of black pycnidia. Stoneman found no true pycnidium; this would indicate relationship of the organism with Volutella rather than with Vermicularia.

V. varians Duc. is described by Ducomet as the cause of a scab-like disease of tomato and potato.[68]

V. subeffigurata Schw. Pycnidia large, scattered, dark, subelevated; spines unequal. On carnation leaves.

V. telephii Karst.[21]

Pycnidia scattered, erumpent, superficial, spherical, dark, 100–150 μ; conidia fusoid bacilliform, acutely curved, 22–32 x 4 μ.

On leaves and stems of cultivated Sedums.

V. concentrica Lev. is reported by Halsted[21] as causing unsightly spots on Dracæna.

V. denudata Schw. A Vermicularia referred to as probably this species is reported as damaging to Kentucky blue grass in Dakota.[70]

V. polygoni-virginica Schw. is reported by Reed & Cooley on rhubarb.[196]



FIG. 342. — Pyrenochæta berberidis, conidiophore and conidia. After Allescher.

An undetermined species is reported as injurious to the potato.[69]

Pyrenochæta de Notaris (p. 482)

Pycnidia globose-clavate, erumpent, leathery or carbonous, black, bristly, ostiolate; conidia ovate, elongate or cylindric; conidiophores branched.

A genus of some thirty species.

P. phloxidis Mas. is common just above ground on living stems of Phlox causing cankers.

P. ferox Sacc. is found on potato stems.

P. oryzæ Miyake[71] occurs on rice in Japan.

Fusicoccum Corda (p. 483)

Stroma subepidermal, several-chambered, erumpent, leathery, black; conidia fusoid, straight and usually large.

Some forty species, several of which are regarded as conidial forms of Diaporthe and Gnomonia.

F. veronense Massal on Sycamore and Oak=Gnomonia veneta. See p. 274.

F. viticolum Red. on grape=Cryptosporella viticola. See p. 280.

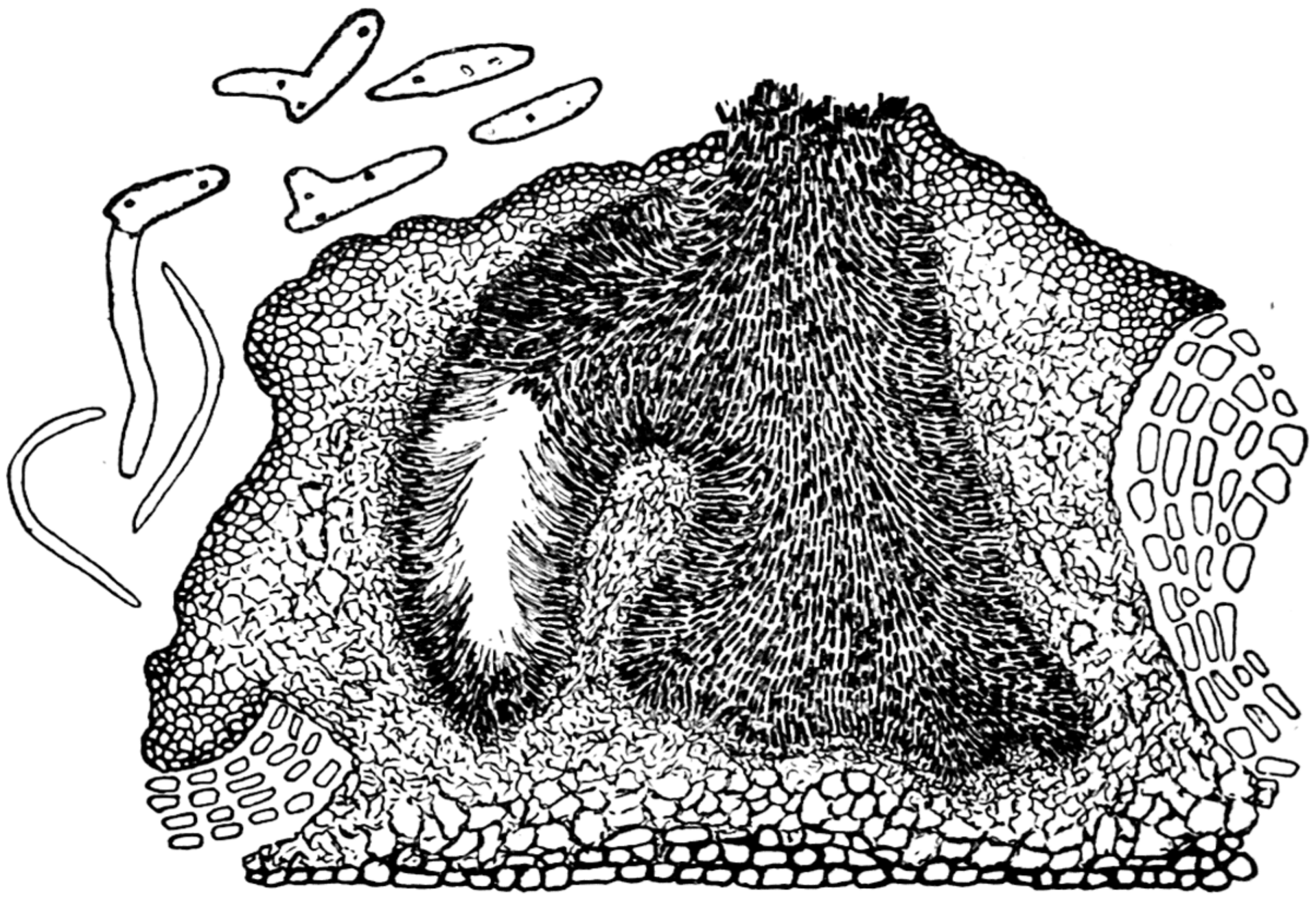


FIG. 343.—F. viticolum, compound pycnidium, germinating spores, paraphyses. After Reddick.

F. amygdali Del. causes a spot disease of almond twigs in Europe.

F. bulgarium Bub. is described as the cause of a grape disease in Austria.[72]

F. perniciosum Briosi & Farm. on chestnut=Melanconis modonia Tul. See p. 281.

Cytosporella Saccardo (p. 483)

Stroma tuberculate or cushion-form, immersed, then erumpent, leathery, black, lighter within; conidia clavate or ovate, usually quite small. Some twenty-five species.

C. cerei, Poll. is on Cereus;
C. citri Maynag. on oranges;
C. damnosa Pet. on pine; all in Italy.
C. persicæ Schw. is reported on young peach branches.

Cytospora Ehrenberg (p. 483)

Stroma superficial or erumpent, tubercular, with irregular chambers; conidia elongate allantoid. Ascigerous forms belonging to Valsa are known.

Some two hundred species, chiefly saprophytes.

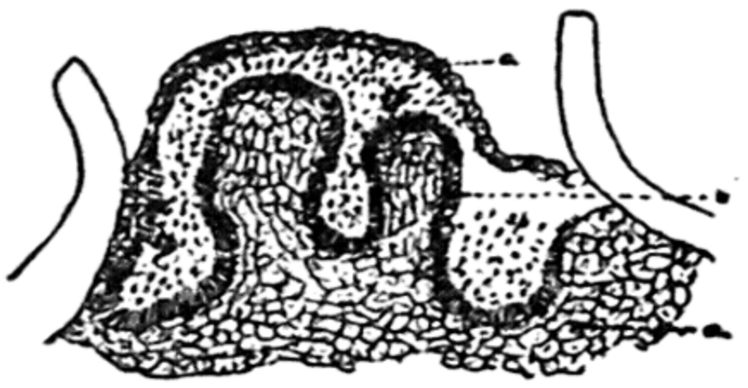


FIG. 344.—Cytospora. Section through a stroma. After Chester.

C. palmarum Cke. is on palms.

C. ceratophora Sacc. is the suspected cause of a blight of Japanese chestnuts.[73]

C. acerina Aderh. causes disease of Acer in Europe.[30]

C. sacchari Butler is found on sugar cane in Bengal.

Dothiorellina Bubak with the one species **D. tankoffiii** Bub. has recently been described as the cause of disease of the mulberry.[327]

Dothiorella Saccardo (p. 483)

Pycnidia erumpent, on a stroma, leathery, ostiole papillate or not; conidia ovate or elongate.

Some seventy species, chiefly saprophytes.

D. ribis (Fcl.) Sacc., on a wide range of hosts=Diaporthe strumella. See p. 279.



FIG. 345.—D. mori. *N*, section of stroma; *O*, conidiophores and conidia. After Allescher.

D. mori Berl. and **D. populi** Sacc. are perhaps parasitic on Morus and Populus respectively.

An unidentified species is reported by Duggar[5] on currant as the cause of cane blight. Inoculations using the conidia have produced the disease. See also p. 283.

Fuckelia Bonordin (p. 483)

Stroma erumpent, globose-pulvinate, substipitate, dark without, lighter within, with several angular pycnidial locules; conidia elliptic.

A single species **F. ribis** Bon. on currants in Europe is a conidial form of Cenangium vitesia. See p. 151.

Ceuthospora Grevielle (p. 483)

Stroma coalescing, erumpent, cushion-shaped, leathery, many-chambered, all chambers opening by a common pore; conidia elongate cylindric, mostly straight.

Some twenty-five species, chiefly saprophytes.



FIG. 346.—C. cattleyæ, a pycnidium. After Delacroix.



FIG. 347.—Plagiorhabdus oxycocci on cranberry. After Shear.

C. coffeicola Del. is of questionable parasitism on coffee;

C. cattleyæ Sacc. & Syd. on orchids.

Plagiorhabdus oxycocci Shear has been reported on cranberry.[197]

Sphærioidaceæ—Phæosporæ (p. 480)

Conidia 1-celled, dark, globose, ovoid or oblong.

KEY TO GENERA OF **Sphæropsioidaceæ—Phæosporæ**

Pycnidia separate
  Pycnidia without mycelium or subicle
    Pycnidia smooth, not hairy
      Conidia in chains, globose. . . . . **1. Sirothecium.**

Conidia not in chains
  Pycnidia sessile, spheroid
    Pycnidia beaked. ..... 2. **Næmosphæra.**
    Pycnidia not beaked
      Conidia spindle-form, with both ends light colored. 3. **Hypocenia.**
      Conidia globose to elliptic
        Pycnidia opening irregularly ..... 4. **Harknessia.**
        Pycnidia opening by a regular ostiole
          Conidia large, ovate to elliptic ..... 5. **Sphæropsis,** p. 501.
          Conidia very small, globose to ellipsoid.... 6. **Coniothyrium,** p. 503.
      Pycnidia stipitate, clavate. ..... 7. **Levieuxia.**
      Pycnidia hairy or setose. ..... 8. **Chætomella.**
Pycnidia with distinct mycelium or subicle
  Pycnidia astomous, in a dark subicle.. 9. **Caprodiastrum.**
  Pycnidia perforate..... 10. **Cicinnobella.**
Pycnidia cespitose or in a stroma
  Pycnidia in dense erumpent clusters..... 11. **Haplosporella.**
  Pycnidia not as above, in a definite stroma
    Stroma applanate or effuse, foliicolous. 12. **Discomycopsis.**
    Stroma dot-like, discoid or hemispheric
      Stroma dot-like, immersed..... 13. **Melanconiopsis.**
      Stroma discoid to hemispheric
        Stroma discoid; spores large..... 14. **Nothopatella.**
        Stroma pulvinate; spores minute, catenulate ..... 15. **Cytoplea.**
      Stroma hemispheric; pycnidia circinate. ..... 16. **Weinmannodora.**

Sphæropsis Léveillé

Pycnidia immersed, erumpent, globoid, black, leathery, membranous, with the ostiole papillate; conidia ovate or elongate, conidiophores rod-like.

About two hundred species several of them important plant pathogens.

S. malorum Pk. [60, 75, 77–81]

Mycelium sooty-brown; pycnidia erumpent, usually surrounded by broken epidermis, apically somewhat depressed; conidia oblong elliptic, brown, usually about twice as long as broad, 22–32 x 10–14 μ, varying in size with host and part attacked.

On apple, pear, quince, hawthorn; on twigs causing canker or blight; on fruit causing rot and on leaves causing spots.

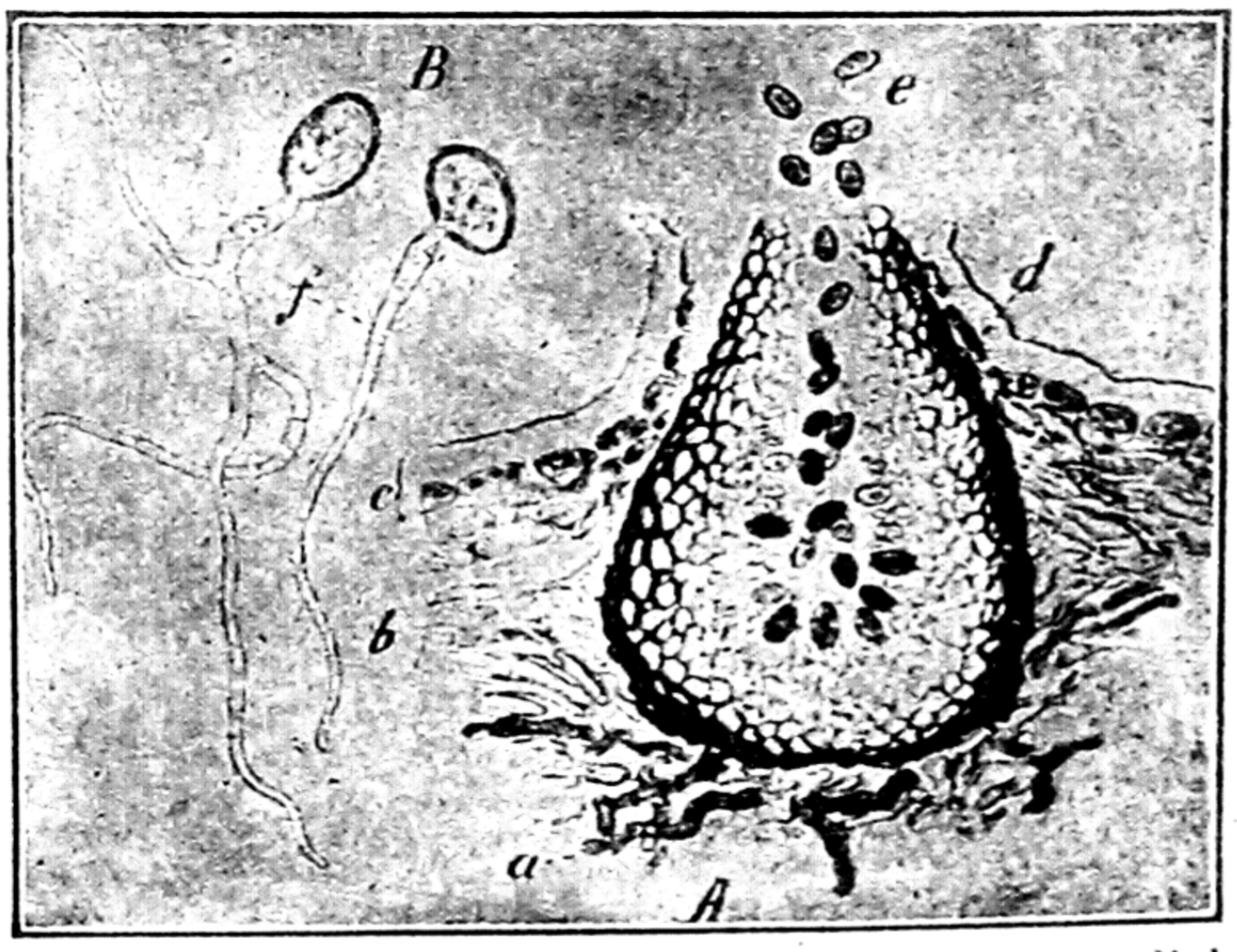


FIG. 348.—S. malorum, *b*, dark colored mycelial threads among the cells of the fruit; *d*, a pycnidium, which has pushed through the epidermis, *c*, and is giving off dark colored spores, *e*; *B*, mature spores germinating in water. After Longyear.

This is one of the common causes of pomaceous fruit rots and of leaf spot in the United States. Its occurrence in leaf spots was noted in 1898,[79] and in 1902 Clinton [80] recognized it as their cause. Cultures were obtained from diseased leaf spots by Scott & Rorer [75] and by inoculations the ability of the fungus to cause spots was definitely proved.

This fungus was reported by Paddock [81] as the probable cause of apple twig blight and canker and cross inoculation between twigs and fruit proved the identity of the fungus on these two parts.

The mycelium is very dark or olivaceous and abounds in the rotten pulp of affected fruit, also in diseased bark, and is even

present in wood though extending but sparingly into woody tissue.

A pycnidial fungus agreeing with S. malorum morphologically has been shown by Shear [82] to be a conidial form of the ascigerous fungus Melanops (=Botryosphæria), see p. 284.

S. pseudodiplodia (Man.) G. & M. [83, 84] causes an apple disease in Europe.

S. mori Berl. parasitizes Morus;

S. ulmi S. & R. the elm;

S. magnoliæ Magnag. the Magnolia in Italy;

S. japonicum Miy. rice in Japan.[16]

S. vincæ S. & W.

Pycnidia gregarious or scattered, globose, immersed, black, small, 260–300 μ; ostiole papillate, erumpent; conidia ovate, ovate-oblong or subpyriform, 17–28 x 10–14 μ. On Vinca.[14]

Many other forms are recorded on various hosts but their parasitism is questionable.

Coniothyrium Corda (p. 501)

Pycnidia subcortical, erumpent or not, globose or depressed, ostiole papillate, black, leathery to carbonous; spores small, ellipsoid, conidiophore reduced or absent.

More than one hundred fifty species.

C. pyriana (Sacc.) Shel. is common on apple leaf spots but is not regarded as their cause.[8]

C. concentricum (Desm.) Sacc. occurs on Yucca, Dracæna, etc.

C. tumefaciens Gus.[85] is described as the cause of a rose canker.

C. melastorum (Berk.) Sacc.[86] is on sugar cane.

C. fuckelii Sacc.[87]

Pycnidia superficial, scattered, dark, 180–200 μ, globose-depressed; conidia numerous, globose to short-elliptic, 2.4–5 x 2–3.5 μ.

The European form is reported on dead and dying branches and a form closely allied to it, probably identical, has been studied in New York as the cause of a raspberry cane-blight. This fungus and no other was present and typical disease followed inoculation. The organism was recovered in pure culture. Both new and old canes died within two months after inoculation.

This is a conidial form of Leptosphæria coniothyrium. See p. 257.[448]

The same fungus was reported by Stevens & Hall[88] and was studied by O'Gara[89] and determined by inoculation and cross inoculating, using pure cultures, to be the cause of rose and apple canker and apple fruit rot.

C. diplodiella (Speg.) Sacc.[34]

Pycnidia minute, subcuticular, erumpent, brown, 100–150 μ; conidia ovoid to elliptic, 7–11 x 5.5 μ; conidiophores simple or branched, hyaline, filiform.

This is the cause of a white rot of grapes and has been reported

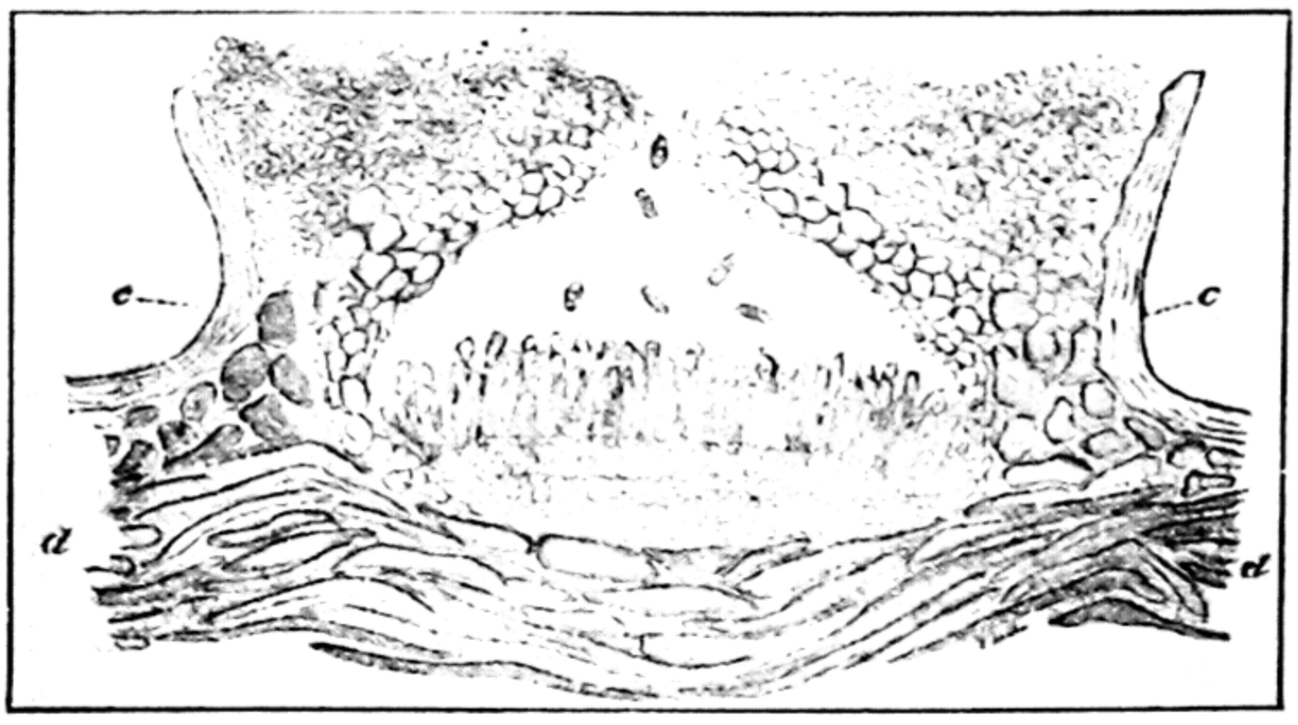


FIG. 349.—C. diplodiella, section through pycnidium. After Scribner.

by Viali & Ravez as belonging to the ascigerous genus Carrinia.[90] See p. 263.

Though probably of American origin it was first recognized in Italy in 1878. In 1887 it caused alarm in France and it was first noted in America in the same year. The mycelium is abundant in the affected pulp and sometimes upon the seeds. Peduncles are often killed. The pycnidia are subcuticular, first pink, then white, later brown.

C. scabrum McA. is the cause of black scurf of citrous fruit in Australia.

C. coffeæ Zimm. is on coffee in Java.

C. vagabundum Sacc. causes premature fall of leaves of gooseberries.

C. japonicum Miy., **C. brevisporum** Miy. and **C. anomale** Miy. are found on rice in Japan.[16]

C. wernsdorffiæ Köck occurs on roses.
C. hellebori C. & M. is found on hellebore.

Sphærioidaceæ—Hyalodidymæ (p. 480)

Conidia hyaline, 1-septate, ovoid, ellipsoid or oblong.

Key to Genera of Sphærioidaceæ—Hyalodidymæ

Pycnidia separate	
Pycnidia not beaked	
Pycnidia in discolored areas, maculicole	
Pycnidia immersed, then erumpent, perforate	
Conidia muticate.	1. **Ascochyta,** p. 506.
Conidia with setæ at the apex. . . .	2. **Robillarda.**
Pycnidia superficial, astomous.	3. **Pucciniospora.**
Pycnidia not maculicole	
Pycnidia hairy.	4. **Didymochæta.**
Pycnidia smooth	
Conidia with an appendage at each end	
Conidia with 1 or more bristles.	5. **Darluca.**
Conidia with cap-like appendages	6. **Tiarospora.**
Conidia muticate	
Conidiophores 1-spored	
Pycnidia without subicle.	7. **Diplodina,** p. 509.
Pycnidia on a cobwebby subicle, phyllogenous.	8. **Actinonema,** p. 508
Conidiophores several to many-spored.	9. **Cystotricha.**
Pycnidia beaked.	10. **Rhynchophoma.**
Pycnidia in a stroma	
Stroma effuse	
Stroma consisting of two distinct layers.	11. **Thoracella.**
Stroma of a single layer.	12. **Placosphærella.**
Stroma verruciform	
Stroma superficial.	13. **Patzschkeella.**
Stroma erumpent.	14. **Cytodiplospora.**

Ascochyta Libert (p. 505)

Usually producing definite spots; pycnidia globose-lenticular, ostiolate; conidia ovate.

About two hundred fifty species.

A. pisi Lib.[21, 91, 92]=Mycosphærella pinodes.[447] See p. 250.

Spots variable in size, roundish, yellowish with brown margin; pycnidia centrally located, black, of angular cells, 5–7 μ; ostiole rounded, surface reddish brown; conidia slightly constricted at the septum, oblong, 12–16 x 4–6 μ; exuded spore-mass brown.



FIG. 350.— A. citri, spores. After Saccardo.

On peas, beans, vetch, Cercis, etc. The pycnidia are visible on the dead areas of the stems, leaves, pods or seeds. The mycelium hibernates in affected seeds, reduces their germinating power and carries the fungus over to the succeeding crop.

A. boltshauseri Sacc. on bean in Switzerland[93] is closely related to the last species.

A. armoraciæ Fcl. is on horse radish, causing leaf spots;

A. ellisii Thüm. on grape;

A. brassicæ Thüm. on cabbage, forming large dull patches; often quite injurious.

A. rhei E. & E.

Spores finally constricted and 1-septate, 7–12 x 3.5–4 μ, hyaline. On rhubarb.

A. viciæ Lib.

Epiphyllous; spots roundish, reddish, margin elevated, orange red; pycnidia minute, clustered, black, 90–100 μ; conidia oblong-ovate, obtuse, slightly constricted, 12–15 x 4–5 μ; exuded mass white. On Vicia.

A. nicotianæ Pass.[94]

Spots between the veins, irregularly scattered, brown; conidia oblong ovate, constricted at the septum. On tobacco.

A. parasitica Faut.

Spots whitish; epiphyllous; pycnidia small, black. Conidia elliptic, 3–4 x 6–10 μ.

This is found associated with rust sori on malvaceous hosts.[17, 95]

A. polemonii Br. & Cav. occurs on Polemonium.

A. piniperda Lin. is parasitic on fir leaves.

A. aquilegiæ Roum. spots columbine leaves.

A. beticola P. & D. is on beet leaves;

A. orobi Sacc. on sainfoin; and **A. oryzæ** Catt. on rice in Italy.

A. lactucæ Rost. is on lettuce;

A. æsculi Bub. & Kab. on Æsculus in Europe;

A. pallida Bub. & Kab. on Acer in Europe;

A. pruni Bub. & Kab. on the cherry in Europe;

A. populicola Bub. & Kab. on the Silver Poplar in Europe;

A. dianthi Berk. on Dianthus and other pinks;

A. violæ Sacc. causing spots on violet leaves;

A. digitalis Fcl. on digitalis;

A. iridis Oud. on Iris.

A. juglandis Bolt. causes spots on leaves of Juglans;[96]

A. aspidistræ Mas. on Aspidistra.

A. fragariæ Sacc.

Perithecia partly immersed, black, 100–125 μ; conidia fusiform to cylindric, constricted, 14–27 x 4–5.5 μ.

This was reported by Dudley[97] as occurring in injurious form near Rochester, N. Y., causing spots, at first red, later brown, on strawberry leaves.

A. primulæ Wail.[26]

Epiphyllous; pycnidia on discolored spots, scattered, depressed globose, 100–110 μ, pale brown, papillate ostiolate; conidia cylindric, obtuse, 5–6 x 2–2.5 μ. On Primula.

A. chrysanthemi Stev.[98]

Pycnidia few, immersed, early erumpent, single or scattered, hemispheric, amber-colored, 100–200 μ; ostiole central, small, often raised by a neck, dark-bordered; conidia oblong, straight or irregular, 3–6.2 x 10–20 μ, apically obtuse, septum often obscure, sometimes more than one; not constricted till germination.

It causes blighting of ray flowers of chrysanthemums.

A. medicaginis Bres.

Spots small, angular, pale, clustered; pycnidia sublenticular, apiculate, pale, becoming black, 200 x 160 μ, context parenchymatous; conidia oblong, obtuse, scarcely constricted, 10–12 x 4–

4.5 μ. According to Stewart, French & Wilson, spots are caused on alfalfa.[99] The American form is distinct from the European and has been described under the name **A. imperfecta** Pk.[443]

A. lycopersici Brum.

Spots red or brown, large, rounded or irregular; pycnidia sparse, minute, black; conidia oblong, constructed, 8–10 x 2.5 μ.

Spots are produced on leaves and fruits of egg plant.

A. caulicola Lau. causes injury to Melilotus alba.[100]

A. cookei Mas. is reported on Sweet William.

A. corticola McA. is the cause of lemon bark-blotch in Australia, killing the trees.[101]

A. graminicola Sacc. occurs on grasses and grains;

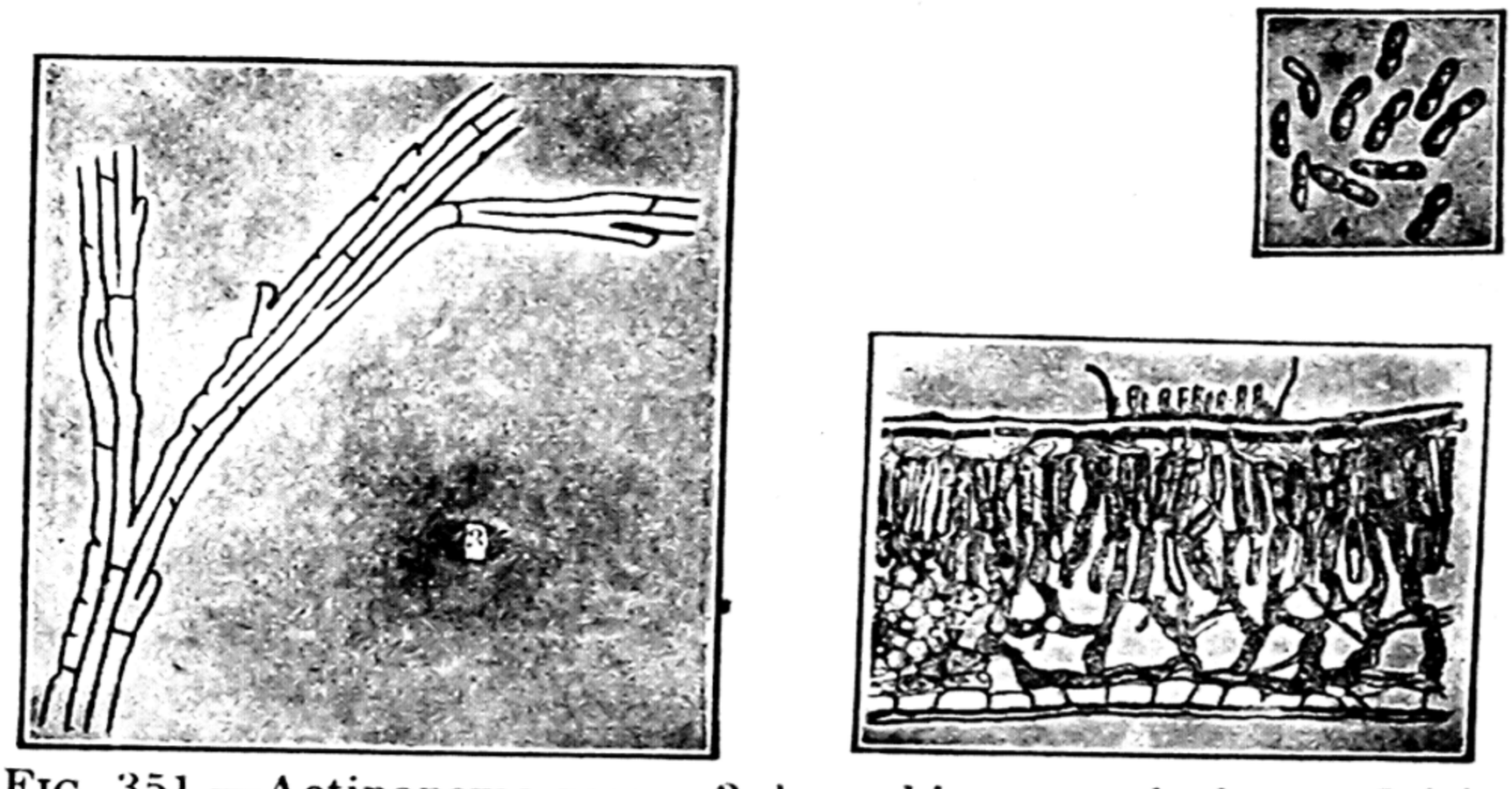


FIG. 351.—Actinonema rosæ. 3, branching strand of superficial mycelium; 4, spores. After Southworth.

A. manihotes Hen. on cassava in Africa.

A. tremulæ Sacc. occurs on aspen;

A. melutispora B. & Br. on ash.

Actinonema Fries (p. 505)

Pycnidia very small, not ostiolate, with a radiating mycelial growth on the surface of the host; conidia elongate, on short conidiophores.

A genus of about fifteen species, chiefly leaf parasites.

A. rosæ (Lib.) Fr.[34, 444]

Spots rounded or irregular, black or purple, epiphyllous, often

confluent, marginally fimbriate, the radiating fibers arachnoid, white, distinctly branched; pycnidia tuberculariform, scattered or confluent, black; conidia oblong, constricted, 18–20 x 5. μ; conidiophores short.

This fungus was first described in 1826. It is common on rose leaves. The mycelium is in part subcuticular, in part deeper. The subcuticular part is visible through the cuticle, consisting of radiate strands each composed of several parallel hyphæ. From this mycelium branches penetrate deep into the leaf. The dark color of the leaf spots is due to discoloration of the contents of the diseased cells; the mycelium itself having little or no color.

A. tiliæ All. causes defoliation of Tilia.

A. fagicola All. occurs on beech leaves;

A. fraxani All. on ash.

Diplodina Westendorp (p. 505)

Pycnidia immersed or erumpent, globose; ostiole papillate, black, small; spores elongate. It differs from Diplodia only in the hyaline spores.

About eighty species chiefly saprophytes.

D. citrullina (C. O. Sm.) Gres. on cucurbs=Mycosphærella cirullina. See p. 246.

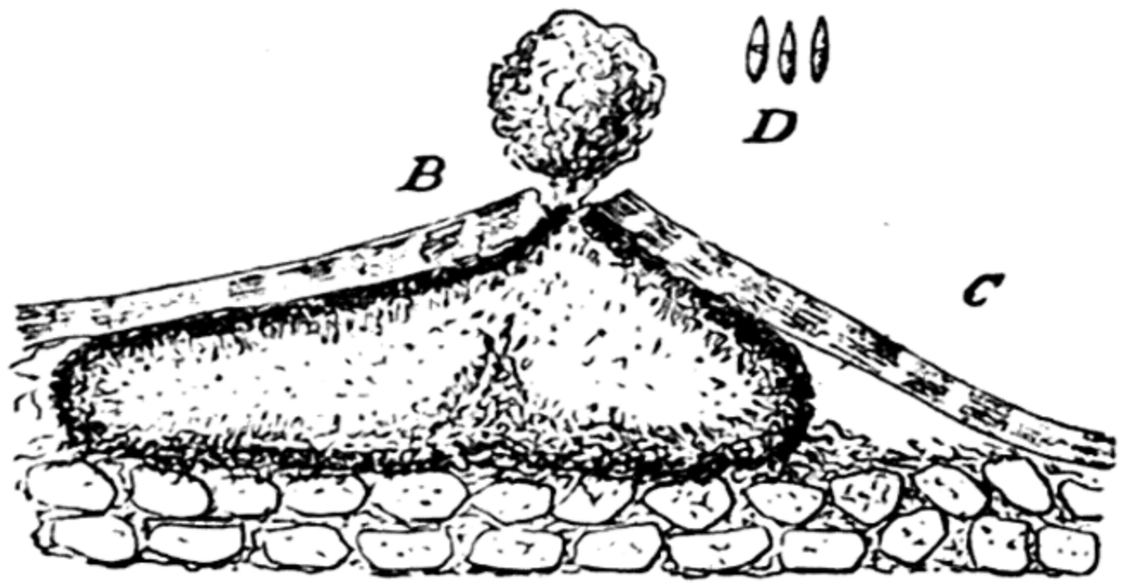


FIG. 352.—D. castaneæ, pycnidium and spores. After Delacroix.

D. castaneæ P. & D. injures chestnut leaves, and causes cankers on the shoots in France, resulting in serious loss.[102]

D. parasitica (Hart.) Prill. occurs on the basal leaves of young shoots of spruce causing defoliation.

D. salicina C. & M. causes tips of willows to die.

D. corticola A. & S. is found on cacao in Africa.

Sphærioidaceæ-Phæodidymæ (p. 480)

Conidia dark, 1-septate, ovoid to oblong.

KEY TO **Sphærioidaceæ-Phæodidymæ**

Pycnidia separate
  Pycnidia beaked
    Pycnidia hairy. . . . . 1. **Rhynchodiplodia,** p. 510.
    Pycnidia smooth. . . . . 2. **Pellioniella.**
  Pycnidia not beaked
    Pycnidia hairy. . . . . 3. **Chætodiplodia,** p. 510.
    Pycnidia smooth
      Conidia with a mucous layer, very large. . . . . 4. **Macrodiplodia.**
      Conidia without a mucous layer
        Pycnidia erumpent, conidia muticate
          Conidia less than 15 μ long. 5. **Microdiplodia,** p. 510.
          Conidia 15 μ or more long. 6. **Diplodia,** p. 511.
        Pycnidia superficial, lignicole. 7. **Diplodiella,** p. 512.
Pycnidia cespitose or in a stroma
  Pycnidia cespitose. . . . . 8. **Botryodiplodia,** p. 513.
  Pycnidia in a stroma
    Pycnidia and subicle enclosed in a hemispheric stroma. . . . . 9. **Lasiodiplodia,** p. 513.
    Pycnidia without subicle, in a globose stroma. . . . . 10. **Diplodiopsis.**

Rhynchodiplodia Briosi & Farneti

Pycnidia rostrate, pilose; conidia oblong.

A single species, **R. citri** B. & F., causes disease of the lemon.

Chætodiplodia Karsten

Pycnidia erumpent, globose, ostiolate, black, membrano-carbonous, hairy or bristly; conidia elongate.

A genus of about ten species, chiefly saprophytes.

C. vanillæ Zimm. is on vanilla.

Microdiplodia Allescher

Pycnidia subcuticular, erumpent, membranous to subcarbonous, globose or depressed, minutely ostiolate; conidia ovoid to oblong, small, (under 15 μ.)

More than twenty-five species, chiefly saprophytes.
M. anthurii Trinch. occurs on Anthurium.

Diplodia Fries (p. 510)

Pycnidia immersed, erumpent, carbonous, black, usually ostiolate-papillate; conidia ellipsoid or ovate; conidiophores needle-shaped, simple, hyaline.

Over four hundred fifty species, many of them saprophytes.

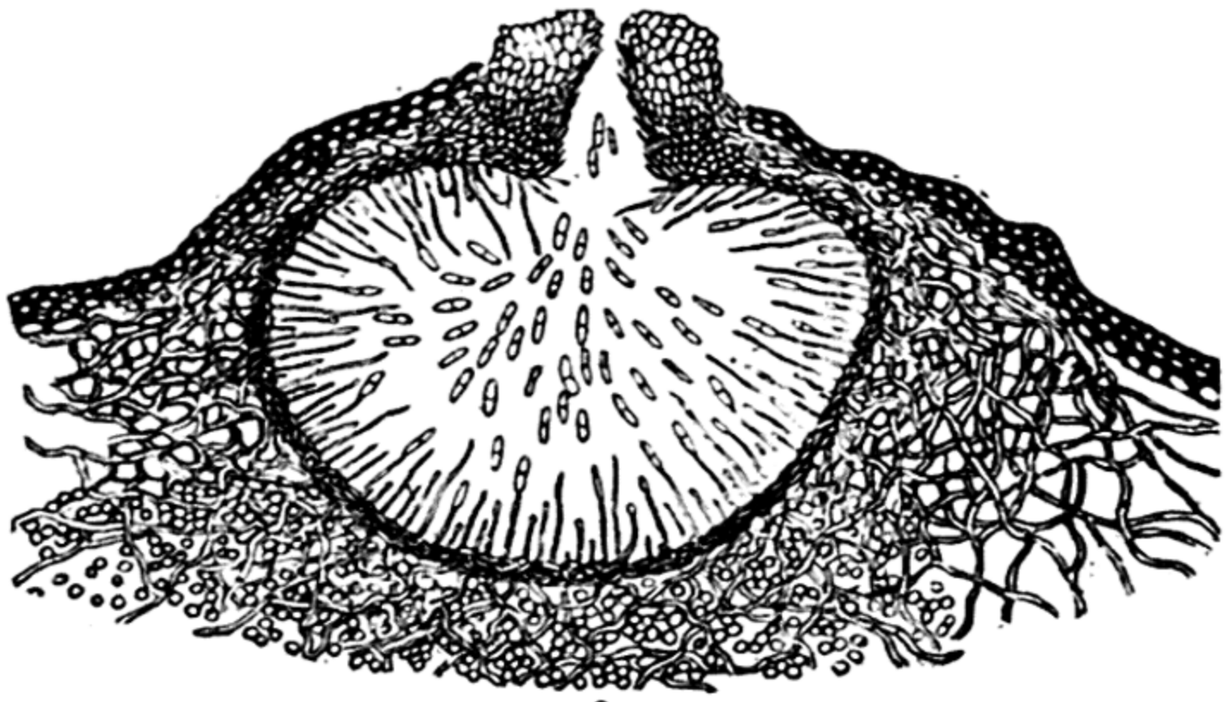
D. zeæ (Schw.) Lev.[103–105]

On ears and stalks of corn, pycnidia borne on the husks, cobs, stalks and rarely the grains, gregarious, small, lenticular to flask-shaped or irregular, papillate; conidia elliptic, straight or curved, constricted or not, 25–30 x 6 μ.

It occurs as the cause of a very serious dry rot of ear corn.

The actual growing mycelium is hyaline and much branched.

Pycnidia in the cob are principally on the scales which surround the inner ends of the kernels and are set in a dense mass of white mycelium. On dead stalks the pycnidia form below the rind, particularly at the nodes, breaking through during the following summer, and extruding the spores in cirri.



2

FIG. 353.—Pycnidia of Diplodia, from corn kernel. After Burrill and Barrett.

The fungus was studied extensively by Burrill & Barrett [103] and inoculations were made using pure cultures. Spores placed under the husk or in the silk, or sprayed upon plants in suspensions, resulted in disease.

Smith and Hedges [106] report that infection is often by way of the root system, the mycelium reaching the grains through the stem and from the cob.

D. macrospora Ea.

Pycnidia scattered, large, erumpent, carbonous; conidia elongate, irregularly clavate, curved or constricted, 70–80 x 6–8 μ.

This is responsible for a corn mold similar to that caused by the last species.[105]

Other parasitic species are:

D. oryzæ Miy. on rice;

D. cerasorum Fcl. on cherries;

D. aurantii Catt. on oranges;

D. mori West. on Morus;

D. gongrogena Temme on Populus in Germany;

D. sapinea (Fr.) Fcl. on conifers;

D. pinea Kick. on pine leaves in Europe; [22]

D. coffeicola Zimm. on coffee;

D. perseana Del. on the avocado.

D. opuntiæ Sacc. is sometimes a serious pest of the cactus.

D. citricola McA. occurs in Australia on lemon twigs, stems and green fruit.[108]

D. destruens McA. is on orange and lemon leaves in Australia;[108]

D. heteroclita D. & M. on Citrus in Algiers.[108]

D. cacaoicola Hen. does much injury to cacao and sugar cane [107] in the West Indies.

D. natalensis Ev. causes a serious black rot of citrus fruits in the Transvaal; [108]

Pycnidia scattered, covered, later erumpent, black; papillate 150–180 μ; spores elliptical, 1–septate, not constricted, dark, 24 x 15 μ, exospore with striated bands.

A Diplodia which cannot be distinguished from this was studied by Fawcett and Burger and is reported as the cause of gummosis of peach and orange in Florida.[247] Pure culture inoculations and cross inoculation showed the same fungus able to cause the disease on both hosts.

D. rapax Mas. is the cause of a stem disease of Para rubber.[54]

D. epicocos Cke. grows on the coconut and an undetermined species attacks ripe pineapples.[54]

Diplodiella Karsten (p. 510)

Pycnidia superficial, globose, ostiolate papillate, black, smooth, rather carbonous; conidia elliptic.

About twenty-five species, chiefly saprophytes on wood.

D. oryzæ Miy. is found on rice.[16]

Botryodiplodia Saccardo (p. 510)

Pycnidia botryose-confluent, erumpent, stromatic, membrano-carbonous, black, usually ostiolate-papillate; conidia elongate or ovate.

Over thirty species, chiefly saprophytes.

An unnamed species of this genus is given by Butler as the probable cause of a coconut palm disease in India.[109]

Lasiodiplodia Ellis & Everhart (p. 510)

Pycnidia collected on a stroma, covered with a brown mycelium, paraphyses among the conidiophores. Otherwise as in Diplodia.

Two species, both parasites.

L. tubericola E. & E.[110]

Pycnidia globose, 250–305 μ; stromatic mass about 1 mm. in diameter; conidia elliptic, 18–22 x 11-14 μ, not constricted; conidiophores short; paraphyses 45–55 μ long, overtopping the conidia.

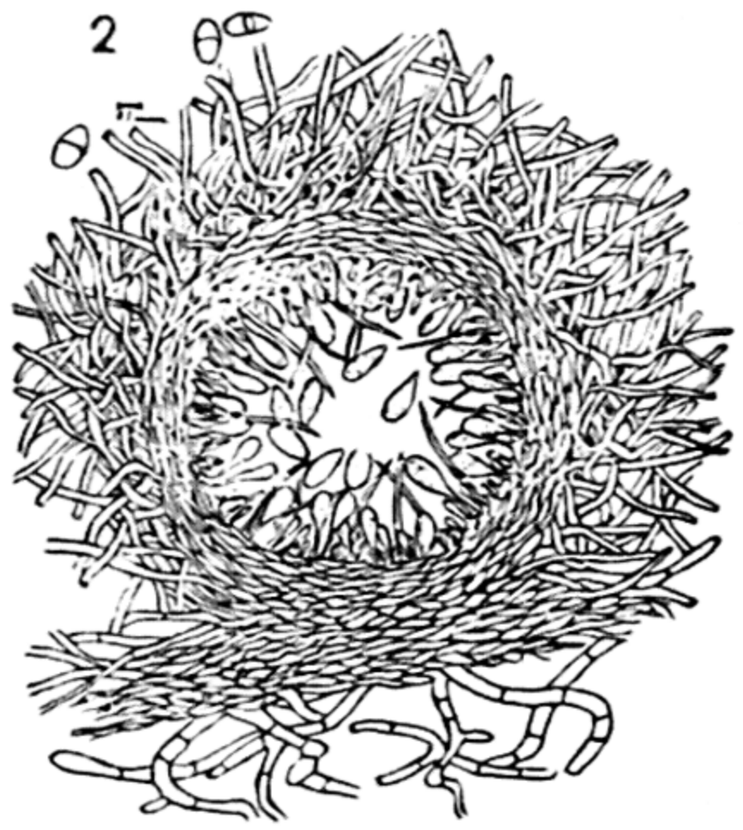


FIG. 354.—Lasiodiplodia tubericola. Perithecium, paraphyses and spores. After Clendenin.

It was found on sweet potatoes from Java which were brought to the Louisiana Experiment Station in 1894.

L. theobromæ (Pat.) G. & M. is a wound parasite of Hevea.

Sphærioidaceæ-Hyalophragmiæ (p. 480)

Conidia hyaline, 2 to many-septate, oblong to fusoid.

KEY TO GENERA OF **Sphærioidaceæ-Hyalophragmiæ**

Pycnidia more or less globose
- Subicle none
  - Conidia appendaged at apex
    - Setæ 1 ..... 1. **Kellermania.**
    - Setæ 3 ..... 2. **Bartalinia.**

Conidia muticate. . . . . 3. **Stagonospora,** p. 514.
Subicle present, dark, phyllogenous. . . . . 4. **Asterostomidium.**
Pycnidia elongate to cylindric. . . . . 5. **Mastomyces,** p. 514.

Stagonospora Saccardo

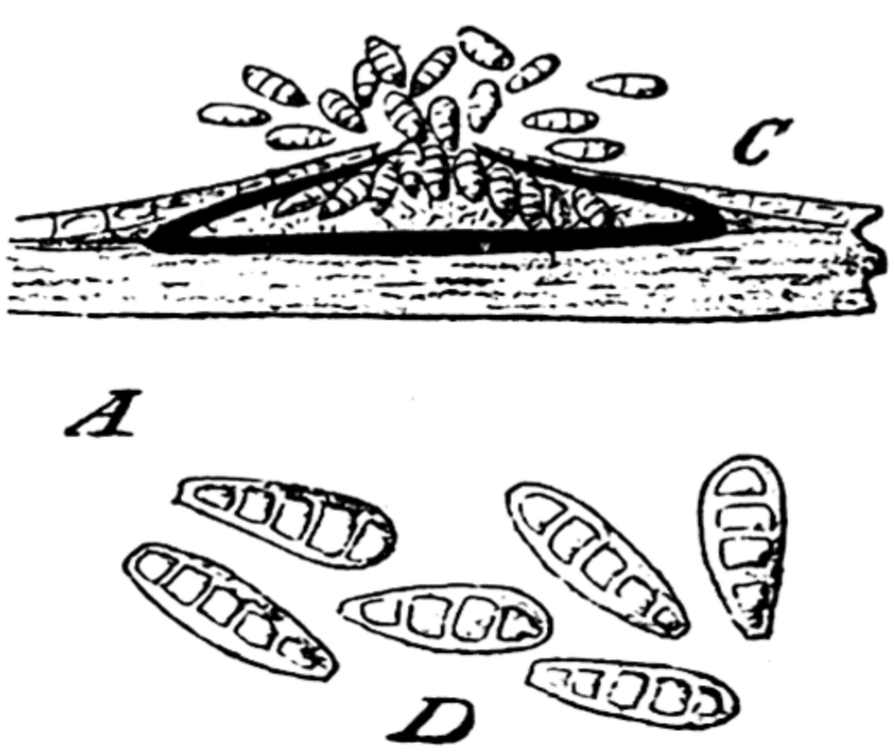


FIG. 355.—Stagonospora. *C*, pycnidium in section. *D*, spores. After Corda.

Pycnidia superficial or erumpent, globose, ostiolate-papillate, black, membranous or subcarbonous; conidia elongate, 3 or more-celled.

Over one hundred species, chiefly saprophytes; differing from Hendersonia only in the hyaline conidia.

S. carpathica Bæuml.

Spots circular, 1–3 mm., light brown with a narrow darker border; pycnidia 120–180 μ; conidia escaping in a gelatinous mass, straight or slightly curved, 14–28 x 4 μ, 2 to 5-celled, frequently slightly constricted.[99] It causes leaf spots on alfalfa.

S. iridis Mass. occurs on iris.

Mastomyces Mont.

Pycnidia gregarious, separate, erumpent, elongate, papillate-ostiolate; conidia fusiform, 3-septate.

There are two species, one of which, **M. friesii** Mont., is probably the conidial form of Scleroderris ribesia, see p. 155, the cause of a relatively unimportant currant disease of Europe.

Sphærioidaceæ-Phæophragmiæ (p. 480)

Conidia hyaline, 2 to several-septate, oblong to fusoid.

KEY TO GENERA OF **Sphærioidaceæ-Phæophragmiæ**

Pycnidia separate
Pycnidia not beaked
Conidia free from each other
Conidia muticate
Pycnidia papillate or subastomous
Pycnidia with flattened base. . . . 1. **Macrobatis.**

Pycnidia globose, without flattened base but on a stellate superficial subicle..... 2. **Couturea.**
Pycnidia without a subicle, erumpent
Pycnidia hairy..... 3. **Wojnowicia.**
Pycnidia smooth..... 4. **Hendersonia,** p. 515.
Pycnidia opening widely, with an operculum
Pycnidia superficial, dark, hairy 5. **Angiopoma.**
Pycnidia immersed, pale, smooth 6. **Lichenopsis.**
Conidia appendaged
Conidia 1-ciliate at each end..... 7. **Cryptostictis,** p. 516.
Conidia 1-ciliate at base..... 8. **Urohendersonia.**
Conidia with a round or cup-like appendage at each end..... 9. **Santiella.**
Conidia united in groups
Conidia united into a fascicle..... 10. **Eriosporina.**
Conidia stellately united..... 11. **Prosthemium.**
Pycnidia beaked..... 12. **Pseudographium.**
Pycnidia in a stroma..... 13. **Hendersonula,** p. 516.

Hendersonia Berkley

Pycnidia immersed, erumpent or not, globose with a papillate ostiole or depressed, membranous or subcarbonous; conidia elongate or fusoid, 2 to many-septate.

Some two hundred fifty species, chiefly saprophytic, although there are several parasitic species.

H. mali Thüm.



Fig. 356. — Hendersonia, hymenium and spores. After Starback.

Epiphyllous; pycnidia disciform, large, scattered, black, on brownish, orbicular, violet-margined spots; conidia clavate, apex rounded, base somewhat acute, not constricted, 12–14 x 4–5 μ.

On leaves of apple in Europe and America.

H. piricola Sacc. is on pear; **H. cydonæ** C. & E. on quince; **H. acicola** M. & T. causes a pine leaf disease.[111]

H. coffeæ Del. is on coffee;

H. oryzæ Miy. on rice;
H. notha Sacc. & Br. on Juniperus leaves;
H. togniniana Poll. on Cycas.
H. foliicola (Berk.) Fcl.[133]

Pycnidia epiphyllous, brownish-black, subglobose, subelliptic or irregular; conidia elliptic to clavate, obtuse, 3 to 5-septate; conidiophores filiform, radiating. On Juniperus and Pine.

Cryptostictis Fuckel (p. 515)



FIG. 357.—Cryptostictis, spores After Starback.

Pycnidia erumpent, globose or depressed, ostiolate; conidia elongate, 2 or more septate, subapically appendiculate with a long hyaline bristle. It differs from Hendersonia chiefly in spore characters.

A small genus of eleven species. chiefly saprophytes.

C. cynosbati (Fcl.) Sacc. and
C. caudata (Preu.) Sacc. occur on the rose, the former on the fruit and branches forming wounds.

Hendersonula Speg. (p. 515)

Stroma black, irregular; ostioles punctiform; spores ellipsoid, several-celled, colored. In part = Plowrightia.

A form on the plum = Plowrightia morbosa. See p. 218.

Sphærioidaceæ-Phæodictyæ (p. 480)

Conidia dark, muriform, oblong to ovoid, rarely radiate or cruciate.

KEY TO GENERA OF **Sphærioidaceæ-Phæodictyæ**

Pycnidia separate
  Conidia not reticulate
    Pycnidia on bark, erumpent..... 1. **Camarosporium**, p. 517.
    Pycnidia on wood, superficial..... 2. **Cytosporium.**
  Conidia reticulate..... 3. **Endobotrya.**
Pycnidia merely locules in a stroma..... 4. **Dichomera.**

Camarosporium Schulzer & Müggenburg (p. 516)

Pycnidia immersed, erumpent, separate, globose, ostiolate, papillate, carbonous or submembranous; conidia ovate to fusiform, muriform, with 2 to many cross walls.

Over one hundred twenty species, chiefly saprophytes.

C. fissum (Pers.) Star. causes injury to roses.

C. viticola (Cke. & H.) Sacc. is reported on grape;

C. mori Sacc. on Morus.



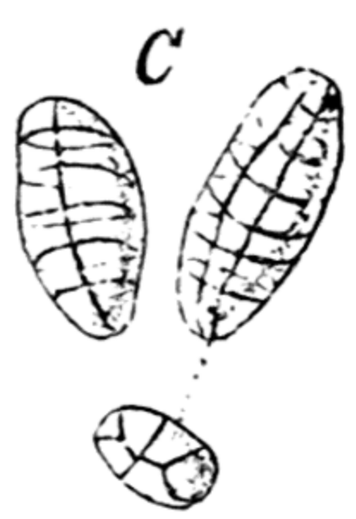


FIG. 358. — Camarosporium, spores. After Starback.

Sphærioidaceæ-Scolecosporæ (p. 480)

Conidia hyaline or light colored, elongate-fusoid, rod-shaped or filiform, continuous or septate.

KEY TO GENERA OF **Sphærioidaceæ-Scolecosporæ**

Pycnidia separate
Pycnidia membranous or carbonous
Pycnidia superficial
Pycnidia hairy
Conidia single on the conidiophores — 1. **Trichocollonema.**
Conidia ternate on the conidiophores — 2. **Gamospora.**
Pycnidia smooth
Pycnidia beaked — 3. **Cornularia.**
Pycnidia not beaked
Conidia usually expelled in a ball — 4. **Collonema.**
Conidia not expelled in a ball — 5. **Septorella.**
Pycnidia immersed or erumpent
Pycnidia hairy, maculicole — 6. **Trichoseptoria,** p. 518.
Pycnidia smooth
Pycnidia beaked — 7. **Sphærographium.**
Pycnidia not beaked
Pycnidia maculicole, mainly phyllogenous
Conidia hyaline — 8. **Septoria,** p. 518.
Conidia colored — 9. **Phæoseptoria,** p. 525.

Pycnidia not maculicole
Pycnidia complete at top, usually papillate. ..... 10. **Rhabdospora,** p. 525.
Pycnidia more or less incomplete at top
Pycnidia gaping, showing a gelatinous spore mass. 11. **Gelatinosporium.**
Pycnidia not exposing a gelatinous mass
Pycnidia foliicole. ..... 12. **Phleospora,** p. 525.
Pycnidia rami-caulicole. . 13. **Phlyctæna.**
Pycnidia suberose, incomplete, often pale
Pycnidia cespitose. ..... 14. **Micropera.**
Pycnidia merely gregarious. ..... 15. **Micula.**
Pycnidia in a stroma
Conidia 4 to 6-fasciculate on a conidiophore. ..... 16. **Eriospora.**
Conidia separate
Conidia setose-penicillate. ..... 17. **Dilophospora,** p. 525.
Conidia muticate
Stroma superficial, setose. ..... 18. **Septodothideopsis.**
Stroma erumpent or immersed
Pycnidia distinct in the stroma, conidia hyaline. ..... 19. **Cytosporina,** p. 526.
Pycnidia as locules in the stroma, conidia colored. ..... 20. **Septosporiella.**

Trichoseptoria Cavara (p. 517)

Pycnidia separate, erumpent, on spots, membranous, hairy; conidia needle-shaped, septate.

A single species. **T. alpei** Cav.[112] is reported by Cavara as injurious to lemon fruits in Italy.

Septoria Fries (p. 517)

Pycnidia immersed, usually on leaf spots, globose lenticular, ostiolate, membranous, black; conidia narrowly elongate to filiform, multiseptate, hyaline, conidiophores very short.

Over nine hundred species, all parasitic, several of them of considerable economic importance but most of them occurring on non-economic hosts.

In part=Mycosphærella, Leptosphæria.

The genus is a very large one similar to Phoma and Phyllosticta except in its spore form and in the ostiole which is frequently very large. Septoria and Phleospora are distinguished only by the lesser development of the walls of the latter and many species which in early stages pass as Phleospora would in older stages be classed as Septoria.

Septoria and Rhabdospora are distinguished only by the part of the host affected, stem or leaf, and many forms in these two genera are undoubtedly identical.

S. pisi West. is on peas.

S. piricola Desm. on pear and apple=Mycosphærella sentina. See p. 246.

S. populi Desm. on Populus=Mycosphærella populi. See p. 250.

S. phlogis Sacc. & Speg. on Phlox=Leptosphæria phlogis. See p. 258.

S. ribis Desm.[113]

Hypophyllous; spots small, irregular, bounded by the leaf veins, brownish-purple; pycnidia innate, minute, convex, brownish-black; cirri in mass reddish; conidia elongate, linear, curved. 50 μ long.

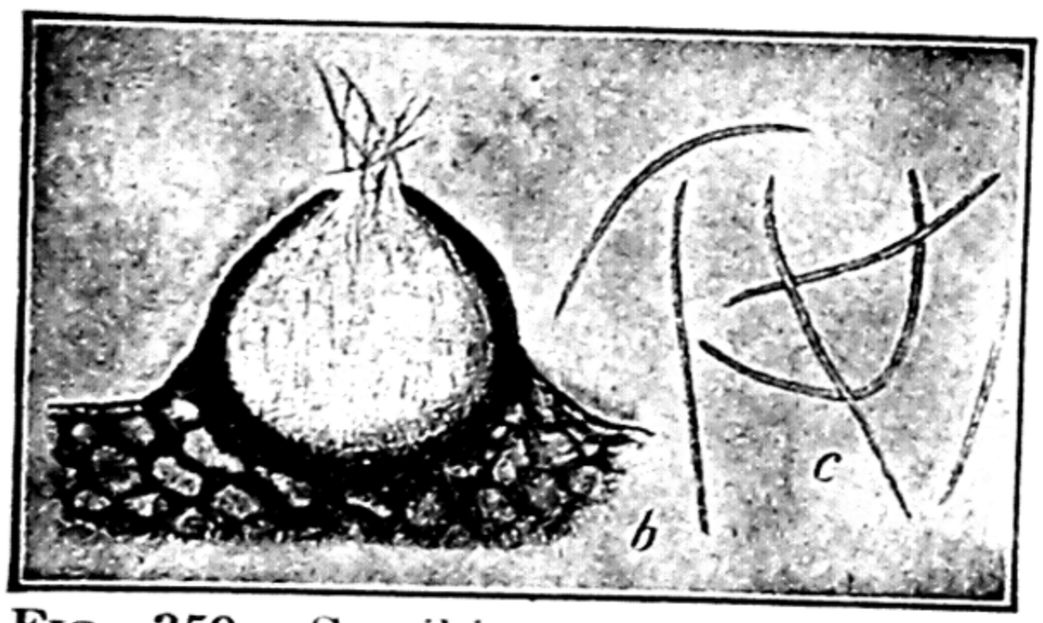


FIG. 359.—S. ribis, a pycnidium and spores. After Longyear.

On gooseberry and currant, causing leaf spots and defoliation.

S. aciculosa E. & E.

Pycnidia innate to superficial, grouped, minute, amphigenous; conidia needle-shaped, continuous, 15–20 x 0.75 μ.

It is found on the strawberry.

S. fragariæ Desm.

Epiphyllous; spots suborbicular, brown, with reddish-brown margin; pycnidia minute, innate, prominent, brownish; cirri white; conidia cylindric, obtuse, 3-septate.

Perhaps =Mycosphærella fragariæ. See p. 244.

On strawberry, cultivated and wild, forming circular leaf spots.

S. cerasina Pk.[114]

Spots scattered or confluent, minute, subangular, brown or reddish-brown; pycnidia pale, collapsing; conidia filiform, straight or curved, 50–75 μ long. On cherry.

S. pruni E.[115]

Spots dark brown, dry, subrotund, soon breaking out, 1–3 mm.; pycnidia brown, immersed, 60 μ; conidia linear, obtuse, 4 to 6-septate, 30-50 x 2 μ. On plum.

S. limonum Pass. and **S. sicula** Penz, occur on citrus;

S. glaucescens Trab. on the mandarin;

S. loefgreni N. on oranges in Brazil;

S. ampelina B. & C. on the grape.

S. longispora Sh. (not Miy.) is found on the cranberry.[197]

S. graminum Desm.[116–118]

Spots slightly elongate, pale, fuscous-margined, limited by the leaf veins; pycnidia seriate or scattered, brownish; conidia very slender, straight or curved, non-septate, but multiguttulate, 55–75 x 1–1.3 μ.

This is a frequent saprophyte or weak parasite on wheat, oats and numerous wild grasses. Under some conditions it becomes an injurious parasite, especially upon winter wheat.

S. tritici Desm. is closely like S. graminum.[116]

It is associated with Leptosphæria tritici on wheat. See p. 258.

S. glumarum Pass. is also found on wheat.

S. nodorum Berk. occurs, particularly at the nodes, on the same host.

S. secalina Jancz. is on wheat and rye leaf sheaths;

S. avenæ Frank. on leaves of oat.

S. longispora Miy. (not Shear) and **S. curvula** Miy. are on rice.

S. betæ West.

Spots pale brown, white in the center, brownish-margined; pycnidia epiphyllous, minute, black, prominent; conidia cylindric, straight or curved, white in mass.

It was noted by Humphrey [119] causing a beet leaf spot.

S. citrulli E. & E.

Spots small, round, white, scattered; pycnidia mostly solitary,

one in the center of each spot, but slightly prominent; conidia cylindric or clavate-cylindric, 10–25 x 1.5–2 μ.

On watermelon leaves.

S. cucurbitacearum Sacc. is also on cucurbits. [17]

S. cannabina Pk. is on hemp producing leaf spots.

S. nicotianæ Pat. is reported from France as the cause of tobacco leaf spotting.[120]

S. dolichi B. & C.

Spots white, with a broad, light brown margin; conidia straight, subfusiform, 3-septate, 40 μ. On cowpeas.[121]

S. medicaginis Rob. & Desm. is on alfalfa.

Spots whitish, angulate-subcircular, confluent; pycnidia lenticular, 70–90 μ; conidia slender, vermiform, tortuous, 60–70 x 1 μ, septate.

S. petroselini Desm.

Spots brown, in age white, amphigenous; pycnidia epiphyllous, minute, olivaceous, prominent; conidia filiform, straight or curved, 35–40 x 1–2 μ. On parsley.

S. petroselini apii Br. & Cav.[25, 122–126]

This common and very destructive fungus on celery leaves was first described in Italy by Cavara and in America it was early noted by Chester [122] and Halsted.[25] The pycnidia are abundant in the leaf spots and in the case of stored celery they are found scattered over the blanched petioles. Essentially it is only host variety.

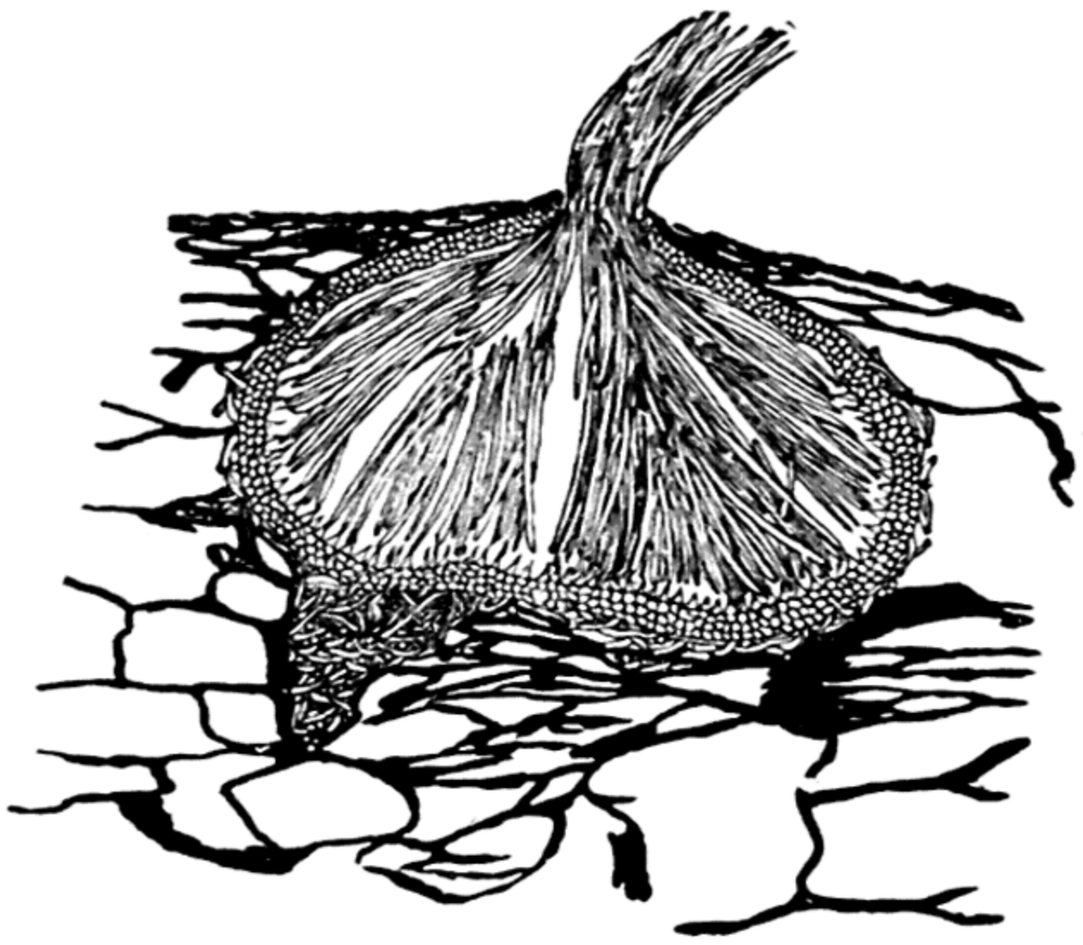


FIG. 360.—S. petroselini apii. Pycnidium showing spores oozing through the ostiole. After Jensen.

S. lycopersici Speg.[22, 127, 128]

Spots large, often confluent and covering the entire leaf, sordid cinereous, subindeterminate; pycnidia scattered, hypophyllous, lenticular-hemispheric, prominent, membranous; conidia elongate, cylindric, 70–110 x 3.3 μ, pluriseptate.

The cause of leaf spots of tomato. It was noted in New Jersey about 1893 [127] and in Ohio in 1896.[128] It is one of the serious tomato pests.

S. lactucæ Pass.[440]

Spots irregular, brownish, angulate, sometimes destroying the entire leaf, pycnidia minute, punctiform, scattered, 90 μ in diameter, conidia filiform, straight or curved, 25–30 x 1.7–2 μ.

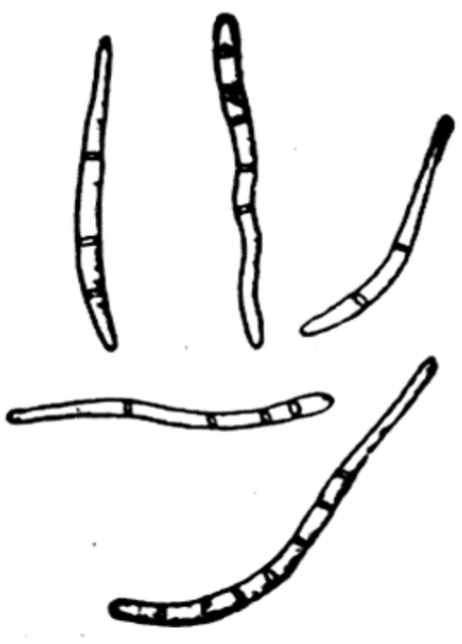


FIG. 361.—Spores of S. lycopersici. After Reed.

On lettuce.

S. consimilis E. & M.[26]

Distinguishable from the preceding by the more indefinite spots, slightly larger pycnidia (90–100 μ) and longer conidia (30–45 x 2–2.5 μ). It causes brown spots on lettuce leaves.

S. armoraciae Sacc.[19]

Spots irregular, ochraceous; pycnidia punctiform, grouped in the center of the spot, 60 μ; conidia filiform, curved, 15–20 x 2–2.5 μ, 1 to 3-septate. On horseradish causing leaf spot.

S. antirrhini Desm. attacks the snapdragon severely.[129]

S. rosæ Desm. is on rose;

S. hydrangeæ Rizz. on cultivated hydrangea;

S. iridis C. Mass. on Iris.

S. cyclaminis Dur. & M. on cyclamen.

S. sedi West.

Epiphyllous; spots circular, gray to gray-brown; pycnidia minute, numerous, brown, scattered, erumpent; conidia cylindric, straight or curved, 5-guttulate; cirri white. On cultivated Sedum.

S. hederæ West. is on Hedera;

S. rostrupii Sacc. & Syd. and **S. varians** Jaff. on chrysanthemum; as is also:

S. chrysanthemella Cav.[26, 130] Spots ochraceous, dark margined; pycnidia epiphyllous, punctiform; conidia 40–50 x 2.5–2 μ, obscurely septate.

It causes damping off of chrysanthemum cuttings and spotting of the leaves.[131]

S. dianthi Desm.[21]

Spots yellowish, oblong, roundish or irregular; pycnidia globose,

depressed, brownish-black; cirri white; conidia elongate, cylindric, curved, obtuse, 30–45 x 4 μ.

It is the cause of a common and injurious leaf spot of the carnation. The pycnidia are visible as dark specks on the blanched background of the spot.

S. azaleæ Vogl.

Spots reddish-yellow; pycnidia amphigenous, immersed, globose to depressed, black; conidia oblong cylindric, filiform, straight or curved, 1 to 3 or more septate, constricted slightly at the septa, 12–18 x 1.5–2.5 μ; conidiophores cylindric, short, 3–5 μ long.

On Azalea.

S. divaricatæ E. & E.

Spots whitish, amphigenous, confluent, purple-bordered; pycnidia numerous, epiphyllous, lenticular, 100–120 μ, dull black; conidia 18–30 x 0.75–1 μ, nearly straight, non-septate, finely guttulate.

It frequently injures cultivated phlox.[14]

S. narcissi Cass. is on Narcissus.

S. exotica Speg. is on Veronicas in cultivation.

S. fairmanii E. & E.

Spots amphigenous, scattered, subangular, 3–4 mm. dark brown, limited by the veins, with a narrow dark margin; pycnidia epiphyllous, scattered, rather numerous, black, subprominent, 100–112 μ; conidia filiform, slightly curved, guttulate, 30–45 x 1.5–2 μ.

It parasitizes hollyhock leaves.[17]

S. parasitica Fau.

Spots amphigenous, white; pycnidia punctiform, innate; conidia cylindric, 30–40 x 3.5–4 μ.

The conidia are broader than in the preceding species and the gross appearance is quite different. It is found associated with rust sori on hollyhock.[17]

S. helianthi E. & K.

Spots brown, definite, 2.5–7.5 mm. with a yellowish elevated margin; pycnidia epiphyllous, immersed, brown, collapsing, 105 μ; conidia linear-filiform, 3 to 5-septate, 30–70 x 2–3 μ.[132]

On sunflower leaves.

S. majalis Aderh. causes a leaf spot of lily-of-the-valley;

S. oleandrina Sacc. In leaf spots of oleander.

S. veronicæ Desm.

Spots amphigenous, small, subrotund, brownish or grayish, becoming white, border umbrinous; pycnidia epiphyllous, globose, prominent, pale brownish-black; conidia elongate, slender, straight or flexuose.

It is parasitic on cultivated Veronicas.[14]

S. caraganæ Hen. is on Caragana.

S. ochroleuca B. & C.

Spots scattered, suborbicular, pale, brown margined; pycnidia central, minute, scattered, hypophyllous, pale, collapsing; conidia fusoid-filiform, curved, continuous or 1-septate, 25 μ long.

In leaf spots on chestnut.

S. castanicola Desm. and **S. castanea** Lev. are on chestnut; **S. nigro-maculans** Thüm. on walnuts and horse-chestnut;

S. æsculi Lib. and **S. hippocastani** B. & Br. on horse-chestnut.

S. pseudoplatini R. & D. occurs on sycamore and maple;

S. fraxani Desm. on ash;

S. cercidis Fr. on Cercis;

S. tiliæ West. on Tilia;

S. curvata (R. & B.) Sacc. on Robinia leaves.

S. spadicea P. & C.[133] causes a common twig blight of pine.

Pycnidia not spot-forming, late, becoming slightly erumpent on inner surface of browning needles, scattered, membranous, fuscous-olivaceous, subimmersed, 190–225 μ in diameter. Spores hyaline, cylindrical, slightly curved or flexuous, apex acute, 1-septate, rarely constricted at septum, 3–4 x 30–45 μ. Conidiophores short.

S. ulmariæ Oud. Pycnidia minute, immersed, spores cylindric, curved, hyaline, continuous, 5.0 x 2.5 μ. On Spirea.

S. cornicola Desm.

Spot orbicular, margin dark purple; pycnidia epiphyllous, few, black; spores cylindric, curved, 35–40 x 2–2.5 μ, obsolete 2 to 4-septate, hyaline. On Cornus.

S. parasitica Hart. is found on young spruce buds killing the lateral shoots.

Phæoseptoria Miyabe (p. 517)

As in Septoria but with colored conidia.
P. oryzæ Miy. is on rice in Japan.

Rhabdospora Montaigne (p. 518)

Pycnidia innate, erumpent, globose or depressed, brown or black; conidia as in Septoria.

Similar to Septoria, but on stems.

R. coffeicola Del. and **R. coffeæ** Del. are on coffee;

R. theobromæ A. & S. on cacao;

R. oxycocci Sh. on cranberry.

R. rubi E. Pycnidia black, subglobose, innate, erumpent, scattered, 100–195 μ; conidia linear, curved, 3 to 4-septate, 40–45 x 3 μ. On blackberry.

Phleospora Wallroth (p. 518)

Pycnidia innate, imperfectly developed, and chiefly formed of modified host tissue; conidia elongate-fusoid, thick, 2 to many-septate. About twenty-five species of leaf parasites.

This genus closely approaches the Melanconiales in structure. Several forms have been shown to be allied to Mycosphærella, e. g., P. ulmi to M. ulmi.

P. mori (Lev.) Sacc. on Morus = Cylindrosporium mori = Mycosphælla.

P. moricola (Pass). Sacc. on Morus is a conidial form of Septoglœum mori.

P. aceris Lib. is found on maple and sycamore leaves;

P. oxycanthæ Desm. on hawthorn leaves;

P. caraganæ Jacz. on Caragana.[134]

Dilophospora Desmazieres (p. 518)

Pycnidia globose, ostiolate, usually stromatic; conidia cylindric, unicellular, with hair-like appendages at each end.

In part = Dilophia.

D. graminis Desm. = Dilophia graminis. See p. 257.

Cytosporina Saccardo (p. 518)

Stroma valsoid, cushion-formed or tubercular; pycnidia sunken, the ostiole erumpent; conidia filiform, curved, 1-celled.

Twenty species of bark and wood inhabiting fungi.

These are, in part at least, conidial forms of the Valsaceæ.

C. ribis Miy.[135] occurs on currant and gooseberry bushes in Holland attacking the cortex, later the wood, and killing the shoots.

Nectrioidaceæ (p. 479)

Pycnidia fleshy or waxy, light colored, globose, rarely cup-shaped or hysterioid; stroma present or absent; conidia various, usually hyaline.

This group contains some twenty-five genera none of which are serious plant pathogens. Some are conidial forms of the ascigerous fungi Aschersonia and Polystigma.

Key to Subfamilies and Groups of **Nectrioidaceæ**

Pycnidia globose, ostiolate	I. **Zythieæ.**
Conidia 1-celled	
Hyaline	1. **Hyalosporæ,** p. 526.
Dark colored	2. **Phæosporæ.**
Conidia two-celled hyaline	3. **Hyalodidymiæ.**
Conidia 3 to several-celled, hyaline	
Elliptic to fusoid	4. **Hyalophragmiæ.**
Bacillar to filiform	5. **Scolecosporæ.**
Pycnidia cupulate or hysterioid	II. **Olluleæ.**

Zythieæ-Hyalosporæ

Conidia hyaline, continuous, ovoid to elliptic.

Key to Genera of **Zythiaceæ-Hyalosporæ**

Pycnidia separate	
Pycnidia smooth	
Pycnidia beakless	
Conidia in chains	1. **Sirozythia.**

Conidia not in chains
Pycnidia on creeping hyphæ. . . . . 2. **Eurotiopsis.**
Pycnidia without mycelium
Conidia spiny or ciliate
Conidia spiny. . . . . 3. **Roumegueriella.**
Conidia with several cilia at apex. . . . . 4. **Ciliospora.**
Conidia smooth
Pycnidia single-walled
Pycnidia more or less papillate. . . . . 5. **Zythia,** p. 527.
Pycnidia with crateriform ostiole. . . . . 6. **Libertiella.**
Pycnidia cup-shaped. . . . . 7. **Lemalis.**
Pycnidia with outer circumscissile wall. . . . . 8. **Dichlæna.**
Pycnidia beaked. . . . . 9. **Sphæronemella.**
Pycnidia hairy or spiny
Pycnidia densely beset with conoid 1-celled setæ. . . . . 10. **Muricularia.**
Pycnidia with slender bristles or hairs
Hairs fasciculate. . . . . 11. **Collacystis.**
Hairs separate
Hairs everywhere but at the apex 12. **Chætozythia.**
Hairs only around the wide ostiole 13. **Pseudozythia.**
Pycnidia cespitose or in a stroma
Pycnidia cespitose, beaked; conidia in chains. . . . . 14. **Treleasiella.**
Pycnidia in a stroma
Stroma more or less pulvinate
Conidia fusoid. . . . . 15. **Aschersonia.**
Conidia globose. . . . . 16. **Munkia.**
Stroma fruticose, branched; conidia bacillar. . . . . 17. **Hypocreodendron.**

Zythia Fries

Pycnidia erumpent or superficial, globose, with more or less evident papillate ostioles, white or bright colored; conidia ovate or elongate.

Some twenty species.

Z. fragariæ Laib. Is said to cause a strawberry disease.

Leptostromataceæ (p. 479)

Pycnidia membranous or carbonous, black, more or less distinctly dimidiate, scutiform, astomous, ostiolate or cleft, erumpent or superficial. Over two hundred species.

Key to Sections of Leptostromataceæ.

Conidia 1-celled	
Hyaline	1. **Hyalosporæ**, p. 528.
Colored	2. **Phæosporæ**, p. 531.
Conidia 2-celled	
Hyaline	3. **Hyalodydimæ.**
Colored	4. **Phæodidymæ.**
Conidia 3 to several-celled	
Hyaline	5. **Hyalophragmiæ**, p. 531.
Colored	6. **Phæopharagmiæ.**
Conidia 1 to several-celled, filiform	7. **Scolecosporæ**, p. 532.

Leptostromataceæ-Hyalosporæ

Conidia hyaline, 1-celled, globose to ovoid.

Key to Genera of Leptostromataceæ-Hyalosporæ

Pycnidia separate	
Pycnidia astomous or variously perforate, but not cleft	
Conidiophores lacking	
Pycnidia on a subicle	
Subicle of fumaginous hyphæ	1. **Eriothyrium.**
Subicle of broad fibers	2. **Trichopeltulum.**
Pycnidia without subicle	
Conidia muticate	
Pycnidia stellately divided or cleft	3. **Actinothecium.**
Pycnidia depressed-clypeate, not stellate	4. **Leptothyrium**, p. 529.
Conidia setulose at each end	5. **Tracyella.**
Conidiophores present, cylindric	6. **Piggotia**, p. 530.

Pycnidia more or less clearly cleft lengthwise
- Pycnidia elongate or lanceolate. . . . . 7. **Leptostroma,** p. 530.
- Pycnidia subcircular. . . . . 8. **Labrella,** p. 530.

Pycnidia in a stroma
- Stroma phyllogenous. . . . . 9. **Melasmia**, p. 530.
- Stroma growing on animal hairs. . . . . 10. **Trichophila.**

Leptothyrium Kunze & Schweinitz (p. 528)

Pycnidia superficial or erumpent, dimidiate, scutiform, membrano-carbonous, black, coalescing or scattered, ostiole variable, structure cellular; conidia ovoid-oblong to fusoid. Some one hundred species.

In part=Gnomonia and Gnomoniella.

L. alneum (Lév.) Sacc. on alder=Gnomoniella tubiformis. See p. 274.



FIG. 362.—Leptothyrium oxycocci. Four spores. After Shear.

L. pomi (M. & F.) Sacc.[136, 137]

Forming minute superficial black spots; pycnidia differentiated in late winter, 25–100 μ; conidia elliptic, 12–14 x 2–3 μ. The mycelium of the spots breaks away and probably functions as a reproductive body.

The fungus is common in sterile form on pomaceous fruits but the sporing stages are rarely found.

L. periclymeni Desm., **L. acerinum** Ktz. and **L. buxi** Pass. are on Lonicera, acer and box respectively

L. oxycocci Sh. [197]

Pycnidia black, dimidiate, amphigenous, scattered, subcoriaceous to coriaceous, irregularly subglobose, subepidermal, erumpent, rupturing irregularly; conidia subfusoid, sometimes slightly curved, pseudoseptate, 10–15 x 2.5–3 μ; conidiophores simple, straight, tapering, slightly longer than the conidia.



FIG. 363.—Leptothyrium oxycocci. Section of a pycnidium, showing its dimidiate character. After Shear.

On cranberry.

L. macrothecium Fcl. is said to cause a strawberry disease.

L. peonæ Br. & Cav. is on peony leaves.

L. parasiticum Poll. is on Cereus stems in Italy.

An undetermined species has been reported as a "fly speck" on cabbage.[138]

Piggotia Berkley & Brown (p. 528)

Pycnidia applanate, inequilateral, thin-membranous, later with a stellate cap which is thrown off forcibly; conidia elongate or cylindric.

A genus of less than ten species.

P. astroidea Berk. & Br. parasitizes elm leaves.

P. fraxini B. & C.

Perithecia hypophyllous; spores oblong, 5–7 μ long. On ash, causing leaf spot.

Leptostroma Fries (p. 529)

Pycnidia dimidiate, subsuperficial, applanate, elongate, black, more or less hysterioid; conidia ovate, elongate or allantoid.

In part=Hysteriaceæ. There are some sixty species.

L. larcinum Fcl. on larch=Mycosphærella larcina. See p. 249.

L. piricola B. & S. occurs on the pear;

L. punctiforme Wallr. on willow.

Labrella Fries (p. 529)

Pycnidia black, round, often indefinite; spores long, fusiform, or spherical, hyaline, continuous.

L. piricola Bres. & Sacc. is on pear leaves;

L. coryli (Desm. & Rob.) Sacc. on Corylus.

Melasmia Léviellé (p. 429)

Pycnidia dimidiate, carbonous, black, often on an effused black stroma; conidia allantoid.

In part=Rhytisma. Over twenty species.

M. acerina Lév. is the conidial form of Rhytisma acerinum. See p. 158. **M. punctata** S. & R. and **M. salicina** Lév. of the two corresponding Rhytismas. See p. 158.

Leptostromataceæ-Phæosporæ (p. 528)

Conidia globose to oblong, 1-celled, dark.

Key to Genera of Leptostromataceæ-Phæosporæ

Pycnidia separate
  Pycnidia on a dark subicle, radiately dehiscent..... 1. **Asterostomella.**
  Pycnidia not on a subicle
    Conidia conglobate, verrucose..... 2. **Discomycopsella.**
    Conidia not conglobate, smooth..... 3. **Pirostoma,** p. 531.
Pycnidia in a stroma
  Stroma membranous
    Pycnidia distinct, exserted..... 4. **Peltostroma.**
    Pycnidia merely locules, immersed.... 5. **Lasmenia.**
  Stroma carbonous; locules many, immersed..... 6. **Poropeltis.**

Pirostoma Fries

Pycnidia separate, shield-shaped, rounded or elongate, leathery, conidia globose to ellipsoid.

A genus of less than five species.

P. farnetianum Poll. occurs on Pandanus in Italy.

Leptostromataceæ-Hyalophragmiæ (p. 528)

Conidia oblong to fusoid, hyaline, 2 to several-septate.

Key to Genera of Leptostromataceæ-Hyalophragmiæ

Pycnidia astomous or ostiolate, not cleft
  Conidia muticate; pycnidia with creeping hyphæ..... 1. **Asterothyrium.**
  Conidia ciliate
    Conidia fusoid, 1-ciliate at each end.. 2. **Discosia,** p. 531.
    Conidia cruciate, each arm 1-ciliate.. 3. **Entomosporium,** p. 532.
Pycnidia rimose dehiscent..... 4. **Cystothyrium.**

Discosia pini Heald has been reported as a parasite on pine hypocotyls.

Entomosporium Léviellé (p. 531)

Pycnidia depressed, subglobose, not ostiolate, black; conidia 4-celled, cruciate, each arm 1-ciliate.

A genus of three species of parasites. In part = Fabrea.

E. mespili (D. C.) Sacc. = F. mespili. See p. 150.

E. maculatum Rev. on pear and quince = F. maculata. See p. 149.

E. thumenii (Cke.) Sacc. occurs on hawthorn.

Leptostromataceæ-Scolecosporæ (p. 528)

Conidia usually hyaline, linear or filiform, continuous or septate.

Key to Genera of **Leptostromataceæ-Scolecosporæ**

Pycnidia astomous or opening variously
  Pycnidia with a round ostiole; conidia catenulate. . . . . 1. **Crandallia.**
Pycnidia astomous or irregularly dehiscent
  Pycnidia with radiate-fimbriate margin. . . . . 2. **Actinothyrium.**
  Pycnidia not radiate-fimbriate
    Pycnidia of two kinds, small simple, and large and loculate. . . . . 3. **Brunchorstia,** p. 532.
    Pycnidia of one kind
      Conidia muticate
        Pycnidia corrugate, not hairy; conidia not separating. . . . 4. **Melophia.**
        Pycnidia hairy; conidia separating into joints. . . . . 5. **Chætopeltis.**
      Conidia ciliate-penicillate at apex. . . . . 6. **Giulia.**
Pycnidia elongate, longitudinally cleft. . . . 7. **Leptostromella,** p. 533.

Brunchorstia Eriksson

Pycnidia erumpent, irregular in form, the smaller occurring singly, the larger as chambers in a stroma, opening by an irregular pore; conidia filiform, septate. A single species.

B. destruens Erik. on pine = Cenangium abietis. See p. 151.

Leptostromella Saccardo (p. 532)

Pycnidia at first covered, at maturity apparently superficial, depressed convex, subcarbonous, dark colored; conidia bacillar or filiform, continuous or septate.

About twenty species, chiefly of no economic importance.

L. elasticæ E. & E.

Spots large, more or less elliptic, whitish, sordid, purplish margined; pycnidia epiphyllous, hysterioid, 0.5–0.7 mm.; longitudinally dehiscent; conidia oblong, hyaline, continuous, 12–15 x 4–5 μ; conidiophores 12–15 x 3–4 μ; obtuse, subolivaceous.

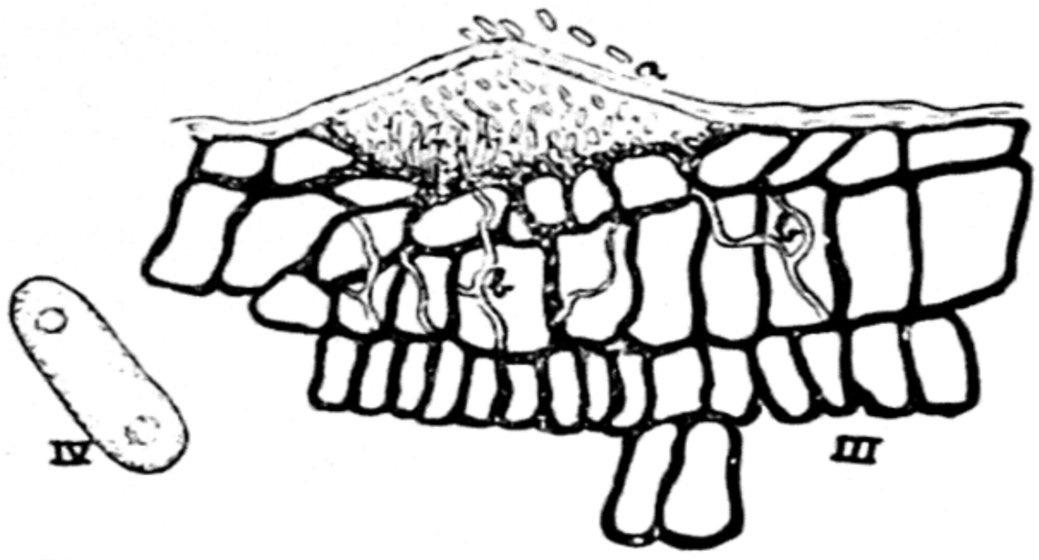


FIG. 364.—Leptostromella elasticæ. After Stone and Smith.

The cause of leaf spots of Ficus elastica.[139]

Excipulaceæ (p. 479)

Pycnidia membranous to carbonous, black, cup-shaped, patellate or hysterioid, at first more or less spherical but at length widely open, erumpent or superficial, glabrous or hairy.

KEY TO SECTIONS OF **Excipulaceæ**

Conidia globose to fusoid, continuous	
Hyaline	I. **Hyalosporæ,** p. 533.
Colored	II. **Phæosporæ.**
Conidia 1-septate, hyaline	III. **Hyalodidymæ,** p. 536.
Conidia 2 to several-septate	
Hyaline	IV. **Hyalophragmiæ.**
Colored	V. **Phæophragmiæ.**
Conidia filiform or bacillar	VI. **Scolecosporæ,** p. 536.

Excipulaceæ-Hyalosporæ

Conidia hyaline, continuous, globose to oblong.

KEY TO GENERA OF **Excipulaceæ-Hyalosporæ**

Pycnidia pilose or setose
  Conidia muticate; pycnidia cupulate. . . . 1. **Amerosporium**, p. 534.
  Conidia ciliate; pycnidia cupulate
    Conidia several-ciliate at apex. . . . . 2. **Polynema.**
    Conidia 1-ciliate at each end. . . . . 3. **Dinemasporium**, p. 535.
Pycnidia smooth or nearly so
  Pycnidia more or less cup-shaped, or disciform
    Pycnidia black
      Pycnidia composed of conglutinate dark hyphæ. . . . . 4. **Godroniella.**
      Pycnidia with cellular context
        Pycnidia cup-like when mature, sometimes obconoid
          Conidiophores simple
            Pycnidia cup-shaped. . . . . 5. **Excipula.**
            Pycnidia terete-conic. . . . . 6. **Catinula.**
          Conidiophores branched. . . . . 7. **Heteropatella.**
        Pycnidia subglobose, disciform or verruciform
          Pycnidia subglobose, irregularly dehiscent and collabent. . . . 8. **Dothichiza**, p. 535.
          Pycnidia disciform, often imperfect and covered by epidermis. . . . . 9. **Discula**, p. 535.
          Pycnidia verruciform; conidia mucose-involute. . . . . 10. **Agyriellopsis.**
    Pycnidia purple. . . . . 11. **Lemalis.**
  Pycnidia hysterioid or valvately gaping
    Pycnidia widely hysterioid . . . . . 12. **Psilospora.**
    Pycnidia valvately gaping
      Conidiophores typically branched. . . 13. **Sporonema**, p. 535.
      Conidiophores simple or none. . . . . 14. **Pleococcum.**

Amerosporium Spegazzini

Pycnidia subcupulate, setulose, conidia cylindric to ellipsoid. Some twenty-five species, chiefly saprophytes.

A. œconomicum E. & T.

Spots orbicular, 2–6 mm., white above with a reddish border, mostly entirely reddish below; pycnidia epiphyllous, erumpent, conic-hemispheric, broadly perforate above, beset with straight, spreading, grayish-black, septate bristles, 100–150 x 4 μ; conidia oblong-fusoid, 18–27 x 4 μ.

Very common on cowpea leaves in circular spots, with dark pycnidia in concentric circles on white background.[436]

Dinemasporium Léviellé (p. 534)

Pycnidia cupuliform, superficial, black, with dark bristles; conidia elongate or allantoid, with apical spines.

Some thirty species, chiefly saprophytes.

D. oryzæ Miy. is on rice.[16]

Dothichiza Libert (p. 534)

Pycnidia erumpent, roundish, somewhat disculate, irregularly dehiscent; conidia elongate or cylindric. In part = Cenangium.

About eleven species, chiefly saprophytes.

D. populea S. & B. parasitizes poplar.[140]

Discula Saccardo (p. 534)

Pycnidia disciform-patellate, imperfectly differentiated from the substratum; conidia ellipsoid, elongate or cylindric.

Some twenty-five or thirty species, chiefly saprophytes.

D. platani (Pk.) Sacc. = Gnomonia veneta. See p. 274.

Sporonema Desmazieres (p. 534)

Pycnidia subepidermal, erumpent, at first closed, then opening radiately; conidia ovate or cylindric.

Some sixteen species, chiefly saprophytes.

S. platani Bäum on Platanus = Gnomonia veneta. See p. 274.

S. phacidioides Desm. = Pseudopeziza trifolii. See p. 148.



FIG. 365. — Sporonema oxycocci on cranberry leaf. After Shear.

S. oxycocci Sh.[197]

Pycnidia amphigenous, excipuliform, thickened at the base,

gradually disappearing above, immersed, erumpent, depressed-globose, gregarious or scattered, 50–100 μ, sometimes collapsing rupturing irregularly by a slit or triangular split; conidia cylindric, straight, 17–19 x 3–4 μ; conidiophores simple, oblong to subglobose, about $\frac{1}{4}$ the length of the spore, or less. On cranberry.

S. pulvinatum Sh. is also on cranberry.

Excipulaceæ-Hyalodidymæ (p. 533)

Conidia hyaline, 1-septate, oblong or fusoid.

Key to Genera of Excipulaceæ-Hyalodidymæ

Pycnidia discoid or patellate
- Pycnidia discoid, veiled; conidiophores simple. ..... 1. **Discella,** p. 536.
- Pycnidia patellate, subsuperficial; conidiophores branched ..... 2. **Pseudopatella.**

Pycnidia hysterioid or irregularly gaping
- Pycnidia hysterioid, elongate..... 3. **Scaphidium.**
- Pycnidia globose, then irregularly gaping; conidia catenulate..... 4. **Siropatella.**

Discella Berkley & Broome

Pycnidia disco-patellate, imperfectly formed; conidia fusoid or oblong. Some twelve or fifteen species, chiefly saprophytes.

D. cacaoicola A. & S. is on cacao in Africa.

The **Excipulaceæ-hyalophragmiæ, Excipulaceæ-phæophragmiæ** contain no important parasites.

Excipulaceæ-Scolecosporæ (p. 533)

Conidia typically hyaline, bacillar or filiform, continuous or septate.

Key to Genera of Excipulaceæ-Scolecosporæ

Pycnidia separate
- Conidia separating at the joints. ..... 1. **Schizothyrella.**
- Conidia not separating
  - Pycnidia discoid, covered, erumpent, margin lacerate; conidia filiform.. 2. **Protostegia.**

Pycnidia mostly cupulate, not lacerate;
conidia hamate. . . . . 3. **Oncospora.**
Pycnidia in a stroma
Pycnidia pezizoid . . . . . 4. **Ephelis,** p. 537.
Pycnidia superficial. . . . . 5. **Pseudocenangium.**

Ephelis Fries

Stroma black, subeffused, sclerotioid; pycnidia pezizoid, sunken in the stroma; conidia cylindric to filiform.

Some seven species, chiefly of no economic importance.

It is a conidial form of Balansia. See p. 209.

Melanconiales (p. 479)

Mycelium internal; true pycnidia never developed, the conidiophores form a stratum; strata typically bearing conidia in acervuli which are immersed or erumpent, black or light colored, waxy, corneous or even submembranous, accompanied by setæ or not; conidia variable.

The common name "anthracnose" is applied to any disease caused by a member of this order.

A single family **Melanconiaceæ** which contains about forty-five genera and over twelve hundred species.

Key to Sections of **Melanconiaceæ**

Conidia globose to elongate
Conidia continuous
Hyaline. . . . . I. **Hyalosporæ,** p. 538.
Colored. . . . . II. **Phæosporæ,** p. 553.
Conidia 1-septate
Hyaline. . . . . III. **Hyalodidymæ,** p. 555.
Colored. . . . . IV. **Phæodidymæ,** p. 556.
Conidia 2 to many septate
Hyaline. . . . . V. **Hyalophragmiæ,** p. 556.
Colored. . . . . VI. **Phæophragmiæ,** p. 557
Conidia muriform, dark. . . . . VII. **Phæodictyæ.**
Conidia long-cylindric to filiform. . . . . VIII. **Scolecosporæ,** p. 561.
Conidia stellate. . . . . IX. **Staurosporæ.**

Melanconiaceæ-Hyalosporæ (p. 537)

Conidia hyaline, 1-celled, globose to oblong, rarely dilute colored.

Key to Genera of Melanconiaceæ-Hyalosporæ

Conidia muticate
Masses, or acervuli, not setose
Conidia not catenulate
Conidia not allantoid
Masses bright colored, subtremelloid..... **1. Hainesia.**
Masses gray to black, rarely bright colored, waxy or horny
Growing, for the most part, on leaves or fruits..... **2. Glœosporium, p. 539.**
Growing usually on twigs of trees or shrubs..... **3. Myxosporium, p. 546.**
Masses black, discoid, horny..... **4. Melanostroma.**
Conidia allantoid..... **5. Næmospora, p. 547.**
Conidia in chains
Masses oblong, hysterioid, dark, hard..... **6. Hypodermium, p. 547.**
Masses discoid, pulvinate or conoid
Masses bright colored, soft..... **7. Myxosporella.**
Masses dark to black
Conidiophores repeatedly branched
Masses discoid; conidiophores dichotomous..... **8. Blennoria.**
Masses depressed-pulvinate; conidiophores verticillate **9. Agyriella.**
Conidiophores simple
Masses scutellate, olive or ashen..... **10. Myxormia.**
Masses truncate, black below, pale above..... **11. Bloxamia.**
Masses setose at margin; conidiophores short, fasciculate..... **12. Colletotrichum, p. 547.**
Conidia aristate with a branched awn at apex..... **13. Pestalozziella.**

Glœosporium and **Colletotrichum** are prominent in pathology as the "anthracnose fungi" and cause many important diseases. The two genera, separated only by the occurrence or non-occurrence of setæ, contain many species which have been transferred from one of these genera to the other on this character, which is to some extent a variable one depending upon the supporting medium, conditions of growth and the particular strain of the fungus under observation.

Many form-species have been described solely on a basis of the hosts affected. Subsequent culture study, and cross inoculation has often failed to sustain these species so that many forms that were formerly considered as distinct are now grouped under one name. No satisfactory disposition of these forms can be made until their ascigerous stages are known and compared and their biologic relations investigated.

Such work as has been done (see page 267) leads rather to consolidation than to segregation of species.

For sake of clearness and convenience, mention is made below of many form species of these two genera under their old names, though the evidence now is that in many instances they should be consolidated with other species.

Glœosporium Desmazieres & Montaigne (p. 538)

Conidial layer subepidermal, disciform or pulvinate, usually erumpent, pale or fuscous; conidia ovate, rarely oblong; conidiophores needle-shaped.

In part=Glomerella, Pseudopeziza, Gnomoniella, Gnomonia, Trochila, Physalospora, Calospora.

There are over three hundred species of parasites, many of them very important pathogens. The spores in germination commonly form dark colored, thick-walled chlamydospores and usually become 1-septate.

G. rufomaculans (Berk.) Thüm. on a large variety of hosts= Glomerella rufomaculans. See p. 264.

G. melengonea E. & H. is reported on egg-plant fruits in New Jersey;[18] **G. orbiculare** Berk. on cucurbs;

G. fructigenum Berk. on many fruits.

G. læticolor Berk. on peaches and apples and **G. versicolor**

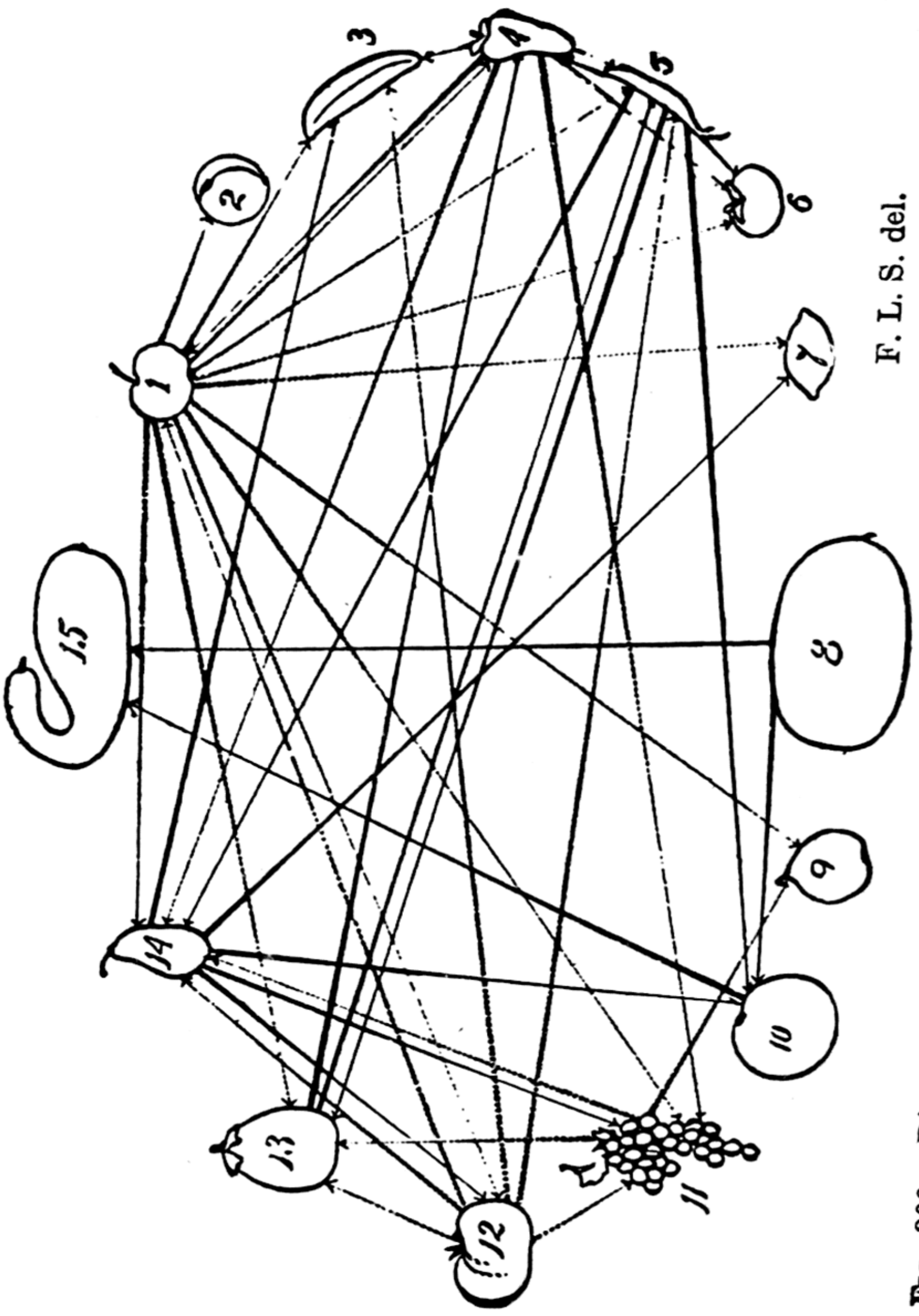


FIG. 366.—Diagram showing inoculations. The dotted lines represent Gloeosporium; the solid lines represent Colletotrichum. The arrow head shows the direction of the inoculations. *1*, Apple; *2*, Peach; *3*, Banana; *4*, Pepper; *5*, Bean; *6*, Persimmon; *7*, Lemon; *8*, Watermelon; *9*, Quince; *10*, Citron; *11*, Grapes; *12*, Tomato; *13*, Egg-plant; *14*, Pear; *15*, Squash.

B. & C. on peaches are probably all identical with Glomerella rufomaculans.

G. salicis West. on Salix=Pseudopeziza salicis. See p. 148.

G. piperatum E. & E. on pepper=Glomerella piperata. See p. 269.

G. cylindrospermum (Bon.) Sacc. on Alnus=Gnomoniella tubiformis. See p. 274.

G. vanillæ Cke. on orchids=Calospora vanillæ. See p. 280.

G. macropus Sacc. on Cattleya=Physalospora cattleya. See p. 253.

G. cinctum B. & C. on orchids=Glomerella cincta. See p. 269.

G. paradoxum (de Not.) Fcl. on Hedera=Trochila craterium. See p. 157.

G. cingulatum Atk. on privet=Glomerella cingulata. See p. 268.

G. psidii Del. on guava=Glomerella psidii. See p. 270.

G. atrocarpi Del. on Atrocarpus=Glomerella atrocarpi. See p. 273.

G. nervisequum (Fcl.) Sacc. on sycamore=Gnomonia veneta. See p. 274.

G. ribis (Lib.) M. & D. on Ribes=Pseudopeziza ribis. See p. 148.

G. bicolor M. Cal. occurs on grapes in Australia.

G. ampelophagum (Pass.) Sacc.[141-143]

Spots subcircular often confluent, from cortex of the berry, centers gray; margin dark or red. Acervuli subepidermal, minute, collected; conidia oblong, ellipsoid or ovoid, 5–6 x 2–3 μ, hyaline.

Small dark spots are produced on fruit, leaf or cane of grape. These later enlarge and show white centers with dark or even red borders. The mycelium lies just below the epidermis. On shoots the cambium is killed and cankers develop. Two kinds of spores have been found by Viala and Pacottet[143] one very small and linear, the other larger and in Phoma-like pycnidia. Common in the eastern United States and Europe.

G. depressum Penz. is on Citrus.

G. spegazzinii Sacc; and **G. intermedium** Sacc. grow on Citrus fruits; **G. citri** Mas., **G. hendersonii** B. & Br. on oranges causing leaf scorch in England, and Trinidad.

G. variabile Lau. grows on Ribes alpinum. **G. curvatum** Oud. is described as a currant parasite.

G. malicorticis Cor.[59]

Caulicolous; spots brownish, slightly depressed, irregular in outline; acervuli minute, erumpent; conidia elliptic, curved, hyaline or greenish-tinged, granular, 24 x 6 μ.

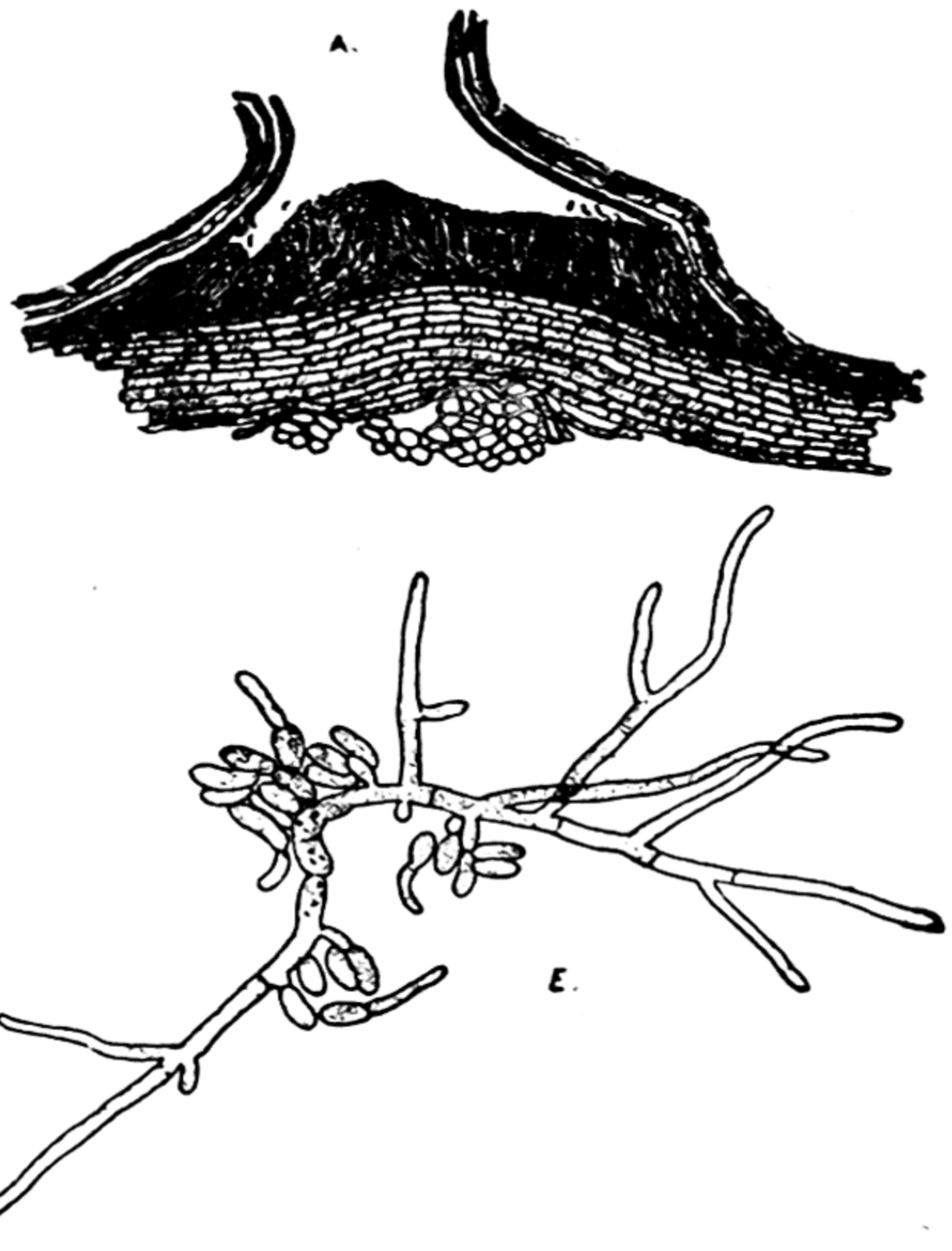


FIG. 367.—G. malicorticis; *a*, acervulus; *E*, germinating spore. After Cordley.

On apples in northwestern United States. Neofabrea has been reported as genetically connected.[446]

G. cydoniæ Mont. is recorded as a parasite on the quince.

G. musarum C. & M. is a common wound parasite on bananas.

Acervuli innate; erumpent, gregarious, rose-tinged; conidia elongate-ellipsoid, ends rounded, 10–12 x 4–5 μ, granular. A variety, **importatum,** is also recognized.

G. diospyri E. & E.

Acervuli on yellowish discolored areas, innate, erumpent, epiphyllous, on the leaf veins, minute, tuberculiform, pale; conidia ovate, granular, 6–14 x 5–7 μ.

On persimmon.

G. fragariæ (Lib.) Mont.

Spots indeterminate, red, epiphyllous; acervuli applanate, rugulose, black; conidia cylindric, 4 to 5-guttulate.

On strawberries but not usually troublesome.

G. amygdalinum Brizi.[145] occurs on the green fruit of the almond in Italy.

G. venetum Speg.[34, 146-148]

Caulicolous or foliicolous; spots orbicular or elliptic, border raised, darker, 2–3 mm. in diameter; conidia oblong, elliptic, 5–7 x 3 μ, in mass amber-colored.

The fungus occurs on all aërial parts of the raspberry and is wide-spread in Europe and America causing serious disease. On canes small purple spots first show near the ground, enlarge and soon develop ashen centers. The leaf spots are small, often scarcely 1 mm. in diameter.

G. mangiferæ Hen. is found on mango leaves in Cuba [149, 150] and other West Indian Islands.

G. olivarum d'Alm. parasitizes olive fruit in Europe.

G. minus Sh. is on cranberry.[197]

G. myrtilli All. is injurious to Vaccinium myrtillus.

G. coffeanum Del. occurs on coffee in Java;

G. pestis Mass. on yam leaves in Fiji.

G. trifolii Pk.[151-152]

Spots subcuticular, brown, suborbicular, concentrically zonate; conidia oblong to cylindric, obtuse, 15–23 x 4–6.3 μ.

The fungus was first observed in America and what was regarded as the same was later seen in Europe as the cause of dying of stems and leaves of clover.

G. caulivorum Kirch.[153]

Caulicolous, spots forming long dark streaks, more or less sunken, blackish-bordered; acervuli minute; conidia curved, more or less pointed, 12–22 x 3–5 μ.

This was said by Kirchner (see [153]) to be the cause of the more serious European anthracnose affecting stem, fruit and leaf of clover. Fulton [154] in 1910 reported it in America and showed that pure cultures of the fungus readily produced infection in wounds or even on unwounded succulent parts when in humid air. The conidia have been known to live twelve months.

G. morianum Sacc. is on alfalfa.

G. medicaginis E. & K.

Acervuli scattered, innate, blackish, rather large, visible on both sides the leaf, opening below; conidia oblong, cylindric, granular, subhyaline, more or less narrowed at the middle, 15–20 x 3–4 μ.

On withered leaves and stems of alfalfa, defoliating the lower part of the stem.

G. manihotis Hen. is found on Cassava in Africa.

G. lagenarium (Pass.) Sacc. on cucumbers is probably identical with Colletotrichum lindemuthianum.

G. concentricum Grev. causes spotting of leaves of cabbage, cauliflower, etc.

G. cattleyæ (P. & D.) Sacc. grows on leaves of Cattleya; **G. dianthi** Cke. on carnation in England. **G. clematidis** Sor. is found on cultivated clematis stems;[157]

G. rosæ Hals.[21] is reported by Halsted on rose canes causing injury similar to that of G. venetum on the raspberry.

G. mezerei Cke. is on Daphne.

G. affine Sacc. grows on various orchids and Hoya. **G. oncidii** Oud. on Oncidium.

G. euphorbiæ Hals. is on clusters and stems of spurge.[21]

G. stanhopeicola Hen., **G. læliæ** Hen. and **G. pallidum** Karst. & Har. are on orchids; **G. helicis** (Desm.) Oud. on English ivy.

G. cactorum Ston. occurs on a number of species of cacti;

G. beyrodtii Klitz on Vanda;

G. opuntiæ E. & E. on Opuntia;

G. elasticæ C. & M. on Ficus;

G. bruneum Petch. and **G. alborubrum** Petch. on Hevea.

G. rhodendendri Br. & Cav. forms yellow spots on various species of Rhododendron.

G. aquilegiæ Thüm is on Aquilegia.

G. violæ B. & Br.[18]

Spots pale, becoming whitish; acervuli very thin, solitary; conidia yellowish. Causing leaf spots on cultivated violets.

G. cytisi B. & Br. is on laburnum;

G. bidgoodii Cke. is on Oncidium;

G. pelargonii C. & M. on Pelargonium.

G. crotonis Del. occurs on Codiæum.

G. soraurianum All. also on Codiæum leaves and described as a dangerous parasite is perhaps identical with G. crotonis.

G. anthuriophilum Trinch. causes spots on Anthurium leaves.

G. begoniæ Magnag. is on begonias in Italy.

G. fagicolum Pass. is widespread and destructive to beech in Germany.

G. umbrinellum B. & Br. is found on Quercus;

G. inconspicuum Cav. on elm;

G. theæ-sinensis Miy. and **G. theæ** Zimm. on tea in Japan and Africa.

G. allescheri Bres. and **G. nanoti** P. & D. occur on Palms.

G. tiliæ Oud. is a serious parasite on the twigs, petioles and leaves on the linden in Denmark.

G. tiliaceum (All.)[158] said to be distinct from the above occurs in Germany on Tilia.

G. juglandis (Lib.) Mont. causes a common, and serious leaf blight of the butternut.[159]

G. fagi (D. & R.) West is on Fagus;

Spots subcircular, fuscous above, olivaceous, vitreous beneath; acervuli small, prominent, honey-colored; conidia oblong ovate, 15–20 x 7–8 μ, minutely 1 to 3-guttulate; conidiophores fasciculate, cylindric, fuscous.

G. apocryptum E. & E. causes a nursery disease of maples and of box elder.[160]

Acervuli numerous, minute, mostly hypophyllous, on dead areas of the leaf; conidia very variable in size, 5–12 x 2½–5 μ, oblong to narrowly elliptic.

G. betularum E. & M.

Spots rounded, 2–3 mm., blackish margined; acervuli amphigenous, brownish, 120–140 μ, becoming cupulate; conidia hyaline, obovate, 9–10 x 5–6 μ.

It is common on leaves of American birches.

Other common species on deciduous trees are:

G. tremulæ (Lib.) Pass. on Populus;

G. betulinum West. on beech;

G. alneum West. on alder;

G. carpini (Lib.) Desm. on Carpinus;

G. coryli (Desm) Sacc. on Corylus;

G. quercinum West. on oak;

G. nervicolum Massal on oak.

G. kawakamii Miy. is found on Paulownia in Japan causing witches' brooms.

G. saccharini E. & E.

Acervuli minute, numerous; spores oblong-fusoid, 6–7 x 1.5–3 μ, hyaline, continuous. On maple.

G. caryæ E. & D. =Gnomonia caryæ.[149]

Spots suborbicular, 1–2 cm., margin subdefinite; acervuli

hypophyllous, numerous, 75–150 μ; spores allantoid, continuous, 7–10 x 1.5–2 μ. On Carya.

G. berberidis Cke.

Hypophyllous; acervuli collected, numerous; spores ovoid, 5 x 3 μ. On Barberry.

G. tamarindi Hem. is on tamarinds, in Africa.

G. canadense E. & E.

Spots amphigenous, center pale, border brownish; acervuli few,



FIG. 368.—M. corticolum, on apple twig. After Edgerton.

180–200 μ; spores ovate-oblong, hyaline, 10–14 x 3.5–4.5.

On white oak.

Myxosporium Link (p. 538)

Acervuli immersed or superficial, indefinite, pallid or reddish; conidia ovate, hyaline or pale, conidiophores slender-cylindric.

Some seventy species, some of which are important pathogens.

In part=Gnomonia. See p. 274.

M. valsoideum (Sacc.) All. on sycamore=Gnomonia veneta. See p. 274.

M. corticolum Edg.

Acervuli erumpent, originating under several layers of cortex, 1–2 mm. in diameter, scattered over the diseased area; conidia straight or curved, cylindric, very densely granular, 18–36 x 6–9 μ, oozing out of the pores in white cirri; conidiophores very short. Very similar to an immature Sphæropsis malorum but considered distinct by Stewart and his associates.[58]

It forms bark cankers in pear and apple in America.

M. longisporum Edg.[161]

Acervuli erumpent, subcorticular, variable in size up to 1.5 mm., scattered over the host in poorly defined rows; conidia straight or curved, 30–48 x 12–15 μ, oozing out in white cirri; conidiophores very short.

On twigs of Liriodendron.

Other parasitic species are:

M. piri Fcl. on pear; **M. mali** Bres. on apple; **M. abietinum** Rost. on conifers; **M. devastans** Rost. on beech; **M. lanceola** S. & R. on oak; **M. carneum** Lib. on beech twigs.

Næmaspora Persoon (p. 538)

Acervuli subgelatinous, indefinite, bright colored; conidia allantoid, short, with a bristle at each end.

N. crocea (Bon.) Sacc. is reported by Massee as the cause of die-back of peach shoots in England.[162]

Hypodermium Link (p. 538)

Acervuli subcuticular, erumpent, elongate, black; conidia ovate-oblong, catenulate.

H. orchidearum Cke. is on Cymbidium.

Colletotrichum Corda (p. 538)

Acervuli innate erumpent, discoid or elongate, dark, surrounded with long black setæ; conidia terete to fusoid; conidiophores short.

The genus is distinguished from Gloœosporium by the presence of setæ, a somewhat unreliable character. See p. 539.

In part=Glomerella and Pseudopeziza. See pp. 264, 147.

Some eighty species, several of them very important plant pathogens.

C. gossypii Sout. on cotton=Glomerella gossypii. See p. 271.

C. cincta Ston. on orchids=Glomerella cincta. See p. 269.

C. rubicolum E. & E. on red raspberry=Glomerella rubicolor. See p. 270.

C. lindemuthianum (Sacc. & Magnus) Briosi & Cavara.[34, 130, 164–167]

Spots subelliptic to irregular, depressed, brownish; acervuli scattered, surrounded by a few not very conspicuous black setæ; conidia oblong, ends rounded, straight or curved, 15–19 x 3.5–5.5 μ; conidiophores cylindric, simple, 45–55 μ.

This fungus, generally known as C. lindemuthianum, is accord-

FIG. 369.—C. lindemuthianum. Showing relation of the fungus to the tissues of the bean. To the left above is a diagram of a section across a bean pod through a canker. The drawing below is a much enlarged largely diagrammatic view of a portion of this same section. It shows how the mycelial threads of the fungus may penetrate the seed coat and enter the starchy tissue of the seed, there to remain dormant until the following season. On the left is a spore germinating and penetrating the epidermis. To the right a magnified view of spores, one germinated. After Whetzel.

ing to the cultural studies of Shear & Wood (see p. 267), probably a variety of Glomerella rufomaculans. See p. 264.

On the bean it attacks stems, leaves, cotyledons, or the pods, producing sunken spots of dead tissue which bear the numerous pink acervuli. It has been shown that the mycelium on the fruit may penetrate through the pericarp and into the seeds beneath and there hibernate.

C. lagenarium (Pers.) E. & H. [139] is probably identical with C. lindemuthianum. It is described as the cause of spots on fruit leaves and stems of cucumbers, watermelons, squash, pumpkins and citron.

C. oligochætum Cav. grows on cucurbs, attacking all parts.[168] Probably=C. lindemuthianum.

C. carica S. & H.[74, 169]

Acervuli brown, becoming black, hemispherical, numerous, small, 85–250 μ, bearing 1–12 (or often 0) long, slender, irregular setæ which are dark throughout, acute, rigid, septate, 2–6 x 22–106 μ, conidia regular, oblong, obtuse, 3.5–6.6 x 8.7–20; conidiophores slender, 1–2 x 45 μ, hyaline.

It is the cause of a decay of figs in the United States.

C. ampelinum Cav. is on grape leaves.

C. glœosporioides Penz.

Acervuli sparse or scarcely gregarious, subepidermal, erumpent, dark, cylindric, setæ continuous or few-septate, dark colored, 40–90 x 5–6 μ, conidia cylindric, straight, 16–28 x 4–6 μ; conidiophores densely fasciculate, cylindric, rounded apically, tenuous, 18–25 x 4–5 μ.

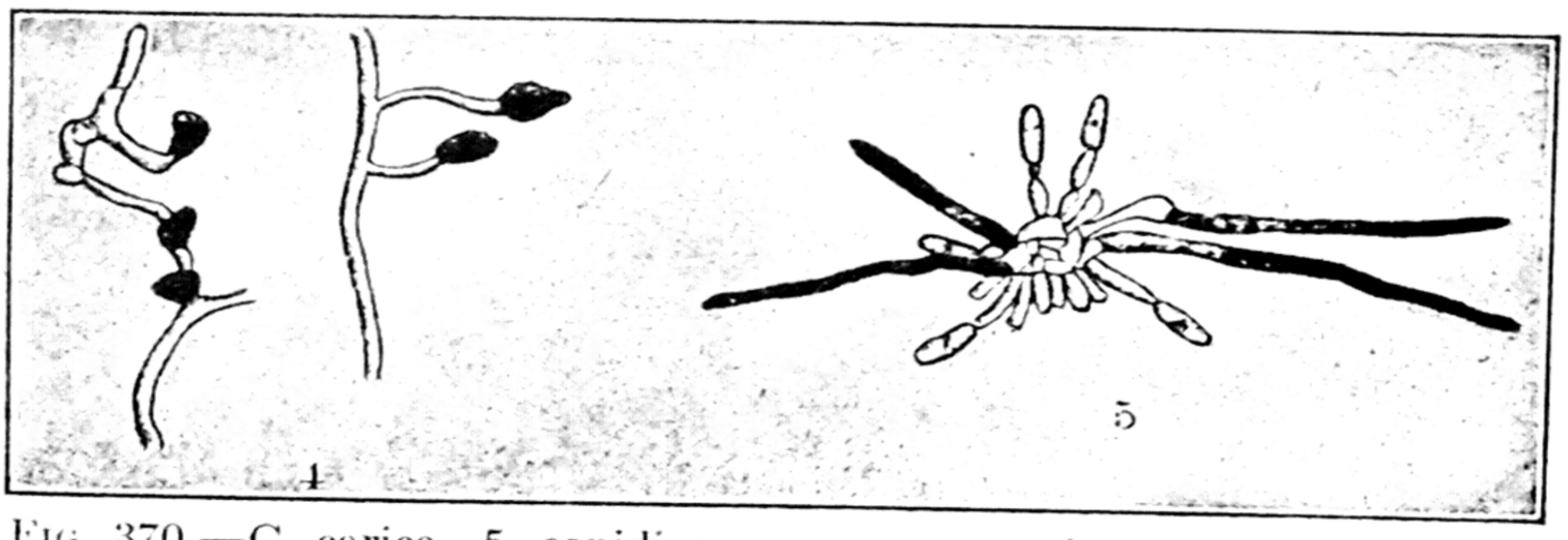


FIG. 370.—C. carica. 5, conidiospores, spores and setæ, 4, black bodies produced on germ tubes. After Stevens & Hall.

It causes "wither tip" of orange, pomelo and lemon,[170-172] spots on citrus leaves, lime canker, and anthracnose of stem and flower with great financial loss in Florida, West Indies, South America, Australia, Malta and many other localities.

In "wither tip" the fungus enters through the terminal bud or from leaves. On lemons attack is through bruises. Acervuli are found on leaf, twig or fruit, breaking through the epidermis. Cross inoculation on the various hosts and with the different forms of the disease demonstrated the identity of all. Smith [173] has questioned the casual relation of this fungus as regards "wither-tip" as it occurs in California.

C. falcatum Went.

Acervuli poorly defined, setæ irregularly arranged, cuspidate,

100–200 x 4 μ, brownish; conidia falcate, 25 x 4 μ; conidiophores ovoid, 20 x 8 μ., hyaline to fuscous.

This is believed to be the chief cause of the red rot of sugar-cane.[175] It was reported in the United States by Edgerton,[174] also by Stevens.[176] Inoculation experiments indicate that it is distinct from C. lineola, on sorghum and Johnson grass, which it resembles morphologically.

C. cereale Manns.[177]

Spots circular to ovoid, 30 mm.; acervuli dark brown, or black; setæ few or many, dark brown to black, at base 6–8 μ thick, tapering to a length of 60–120 μ, continuous or 1 to 2-septate;

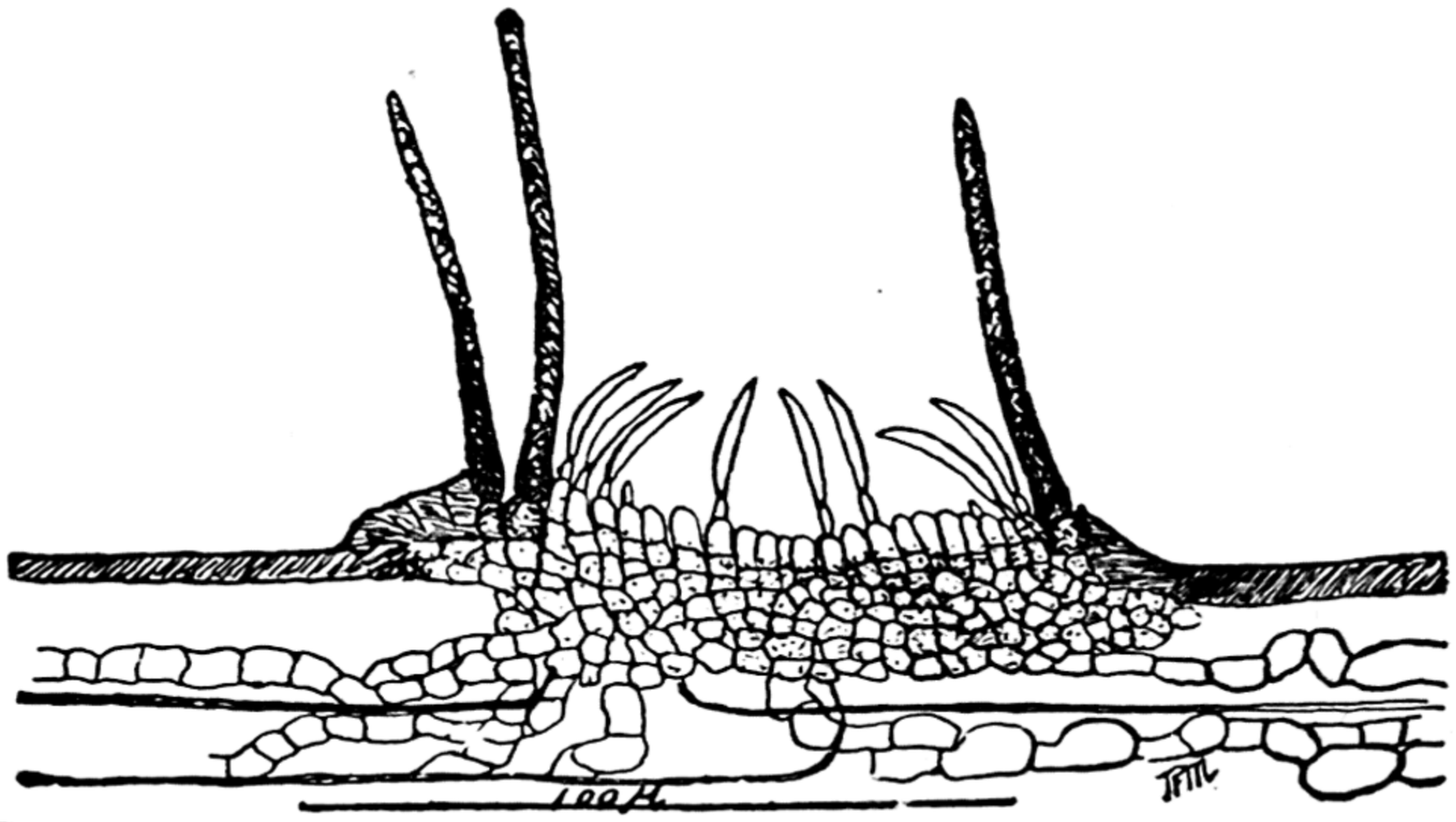


FIG. 371.—C. cereale, acervulus showing mycelium, setæ, conidiospores and spores. After Manns.

conidia 18–26 x 3–4 μ, spindle to boat-shaped, 2 to several-guttulate; conidiophores, very short, 12–6 x 1–2 μ.

This fungus is parasitic on the roots, stems, blades and spikes of rye, wheat, oats, barley, emmer, orchard grass, timothy, blue grass and chess. The disease causes a premature ripening and shrivelling of the grain. Superficially the diseased heads present the same appearance as those attached by scab (Fusariose) but no pink over-growth is present, nor is the presence of the disease always apparent, as it was found on numerous heads of grain which appeared to be healthy. Morphological studies indicate that all the hosts mentioned above are affected by the same fungus. This was confirmed by cross inoculations in the case of wheat and emmer.

C. trifolii Bain.[178-180]

Spots dark, depressed; acervuli erumpent, scattered or gregarious; conidia straight, ends rounded, 3–4 x 11–13 μ; conidiophores cylindric or fusoid, hyaline; setæ few or many, continuous or uniseptate, dark, paler apically, 4–7 x 39–62 μ, sinuous, or nodose.

It occurs as an anthracnose producer on stems, rarely on leaves, of clover and alfalfa causing very serious injury. In general appearance it is much like Glœosporium caulivorum.

C. spinaciæ E. & H.[20]

Spots roundish, dirty-white, or greenish, 2–4 mm., with a slightly raised border; acervuli amphigenous, punctiform, 40–75 μ, with 3–12 erect or spreading bristle-like setæ, 60–75 x 4–4.5 μ, subbulbous at base, subhyaline, subacute above, dark brown below; conidia subfalcate, fusoid, 2 to 4-guttulate, 14–20 x 2.5–3 μ, ends subacute; conidiophores short.

It produces blotches on spinach leaves.

C. phomoides (Sacc.) Ches.[29, 66, 154-157, 181]

Spots depressed, circular, slightly discolored, center black, 5–10 mm., later irregular and confluent; acervuli abundant, densely gregarious, rusty brown to black, applanate, 95–150 μ; setæ abundant, fuliginous, generally curved, septate, 65–112 μ; conidia oblong, 16–24 x 4 μ, ends subacute; conidiophores short, slender, 30–40 μ high, arising from a well developed stroma. On tomato.

This is a common cause of ripe rot of tomatoes. The fungus was studied in culture by Stoneman [66] who reported it as somewhat different from G. rufomaculans, though Edgerton [156] thought the apple and tomato forms the same. Work by Gueguin [154] throws doubt on the American form on tomato being identical with the European form known as G. phomoides. Chester [155, 442] has reported what he regarded as the last species as setigerous.

C. nigrum, E. & H.[19, 25]

Spots blackish, depressed; decaying; acervuli numerous, superficial; setæ numerous, slender, setæ pointed; conidia oblong.

This form which appears quite different from G. piperitum was described from New Jersey by Halsted.

C. malvarum Br. & Casp.[182] (=C. althæa.)

Epiphyllous and caulicolous; spots brown, sunken; acervuli erumpent; setæ dark brown, abundant, 1 or 2-septate, usually colorless below, 60–109 x 3–5 μ, appearing after the conidiophores which are colorless, cylindric, tapering slightly and apically rounded, slightly longer than the conidia; conidia irregular, oblong, granular, flesh-colored in mass, 11–28 x 5 μ.

It is described by Southworth [182] as the cause of anthracnose of the hollyhock. The fungus closely resembles C. lindemuthianum but cross inoculations on the bean failed to produce disease though on hollyhock inoculations succeeded easily.

C. schizanthi Jensen & Stewart was found on greenhouse Schizanthus plants in Ithaca.[315]

C. agaves Sacc.

Spots pale; acervuli conic; setæ few, 90–100 x 5–6 μ, brownish ochraceous, 2 to 3-septate, conidia 22–26 x 4–5 μ; conidiophore subramose, fuscous at base. On sisil hemp and agave.[183]

C. bletiæ Hals. is on Bletia.

C. violæ-tricoloris R. G. Sm.[184-185]

Spots pale-yellow on leaves. Dead areas on petals occur with more or less deformity of blossom. Spots at first orbicular and definite, later confluent and irregular, acervuli numerous, 50–150 μ, often confluent; stroma usually poorly developed; setæ mostly single or in pairs, 20–70 μ, deep brown, 1 to 2-septate, tapering gradually to a point; conidia oblong or slightly curved, ends blunt, 20 x 5 μ; conidiophores short, hyaline.

It causes spotting of pansy leaves in several states and leads to failure to bloom.

C. anthurii Del. occurs on Anthurium;

C. luxificum H. & D. on cacao in the West Indies;

C. elasticæ (C. & M.) Koo. on Ficus.

C. primulæ Hals.[26] is reported as causing a leaf disease of the primrose.

C. kentiæ Hals. is on palms.[21]

C. omnivorum Hals.

Spots dry, irregular in outline; conidia 20–28 x 3–5 μ, falcate; setæ elongate, acute, black.

On Aspedistra and other plants.[25]

C. camelliæ Mas. is on tea.

C. antirrhini Stew.[186]

Spots depressed, elliptic or orbicular, often confluent, 3–10 mm, acervuli numerous, crowded; stroma well developed; conidia 16–21 x 4 μ, straight or curved, ends rounded; conidiophores short; setæ abundant, dark brown, 50–100 μ, simple, mostly straight and tapering uniformly to a subacute point.

It attacks the stems and leaves of the cultivated snapdragon producing sunken spots.

C. cyclamenæ Hals. is on Cyclamen;

C. dracænæ Hals. on Dracæna;

C. coffeanum N. is on coffee; [187]

C. heveæ Petch. on Hevea in India;

C. cradwickii Banc. on cacao pods; [54]

C. brachytrichum Del. on cacao leaves; [54]

C. theobromæ A. & S. and **C. theobromicolum** Del. are on cacao.

C. incarnatum Zimm. is on Hevea and vanilla;

C. macrosporum Sacc. on vanilla;

C. pollaccii Maynag. on Japanese loquot in Italy;

C. hedericola Lau. on Hedera.

Undetermined species of Colletotrichum have been reported on asparagus,[188] carnation,[25] pear,[26] and many other hosts.

Melanconiaceæ–Phæosporæ (p. 537)

Conidia dark, continuous, globose to oblong or fusoid.

Key to Genera of Melanconiaceæ-Phæosporæ

Conidia solitary on the conidiophores	
Conidia globose or oblong.....	1. **Melanconium**, p. 554.
Conidia fusoid, often arcuate	
Conidiophores not swollen at base. ...	2. **Cryptomela.**
Conidiophores swollen at base.....	3. **Basiascum.**
Conidia in chains	
Conidial chains separate..	4. **Trullula**, p. 554.
Conidial chains in a mucose head.....	5. **Thyrsidium.**

Melanconium Link (p. 553)

Acervuli subcutaneous, conic or discoid, black; conidia elongate to globose-oblong, erumpent in black masses; conidiophore simple. In part=Trichosphæria. See p. 228.

More than one hundred fifty species.

M. fuligineum S. & V. Cav.[34]

Acervuli scattered or gregarious, at first gray-cinereous, then brownish, subepidermal, erumpent; conidia ovoid to ellipsoid, inequilateral, acute, 9–12 x 4–6 μ, olive, guttulate; conidiophores filiform, from a well developed stroma.

It causes the important bitter rot of ripening grapes, especially the white varieties, occurring also on shoots and peduncles. Acervuli appear on the surface of the rotted berries. The mycelium penetrates even to the seeds.

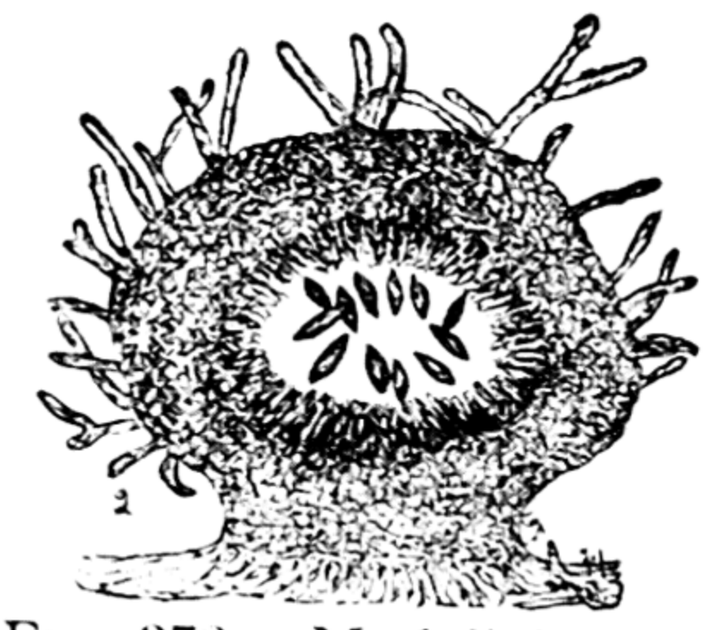


FIG. 372.—M. fuligineum. After Atkinson.

Southworth suggested in 1891 [191] that this and Glœosporium are congeneric but Atkinson [190] who studied the fungus in pure culture thinks them generically distinct. Noack [189] who studied what he regarded as the typical M. fuligineum says that it is preceded by and belongs to a Glœosporium-form.

M. pandani Lév. is a common parasite on Pandanus in greenhouses, killing the branches.

M. sacchari Mass.[192]

Acervuli numerous, collected in indeterminate pallid orbicular spots; conidia cylindric, 10–15 x 3–4 μ, straight or slightly curved, olivaceous, smooth.

In leaves, sheaths and culms of sugar cane. The cause of the rind disease.

Trullula Cesati (p. 553)

Acervuli subcuticular, erumpent, discoid-pulvinate, or conical-depressed, black; conidia oblong-cylindric, catenulate; conidiophores long, bacillar, simple or branched.

Some twenty species, of trifling economic importance.

T. vanillæ Hen. is on vanilla in Africa.

Melanconiaceæ-Hyalodidymæ (p. 537)

Conidia hyaline, 1-septate, ovoid to fusoid.

Key to Genera of Melanconiaceæ-Hyalodidymæ

Conidia mutic	
Saprophytic, on stems and fruits.....	1. **Septomyxa.**
Biogenous, typically on leaves.	2. **Marssonia,** p. 555.
Conidia 3 to 4-ciliate at each end.....	3. **Glœsporiella.**

Marssonia Fisch

Acervuli globose-discoid, pale, conidia ovate to elongate. In part =Gnomonia, Trochila, Pseudopeziza.

Some seventy-five species, all leaf parasites, several of economic importance.

M. castagnei (D. & M.) Sacc. on Populus =Trochila popularum. See p. 157.

M. juglandis (Lib.) Sacc. on walnut =Gnomonia leptostyla. See p. 275.

M. populi (Lib.) Sacc.

Spots suborbicular, epiphyllous, separate or confluent, brown, darker margined, acervuli convex to applanate, fulvous; conidia obovate to subpyriform, 20 x 12 μ, constricted at the septum, straight or curved.



Fig. 373.—M. perforans, conidiospores and spores. After Selby.

It is common on leaves of Populus as the cause of blighting of lateral twigs. It is injurious in nurseries.[26]

M. panattoniana (Berl.) Mag. is found on lettuce in Italy;

M. secalis (Oud.) Mag. on rye;

M. martini S. & E. on oak;

M. potentillæ (Desm.) Fisch as the cause of a disease of the strawberry in Europe.

M. rosæ Trail causes premature fall of rose leaves.

M. perforans, E. & E.[128]

Spots small; irregular, 1–2 mm., pale, soon deciduous; acervuli

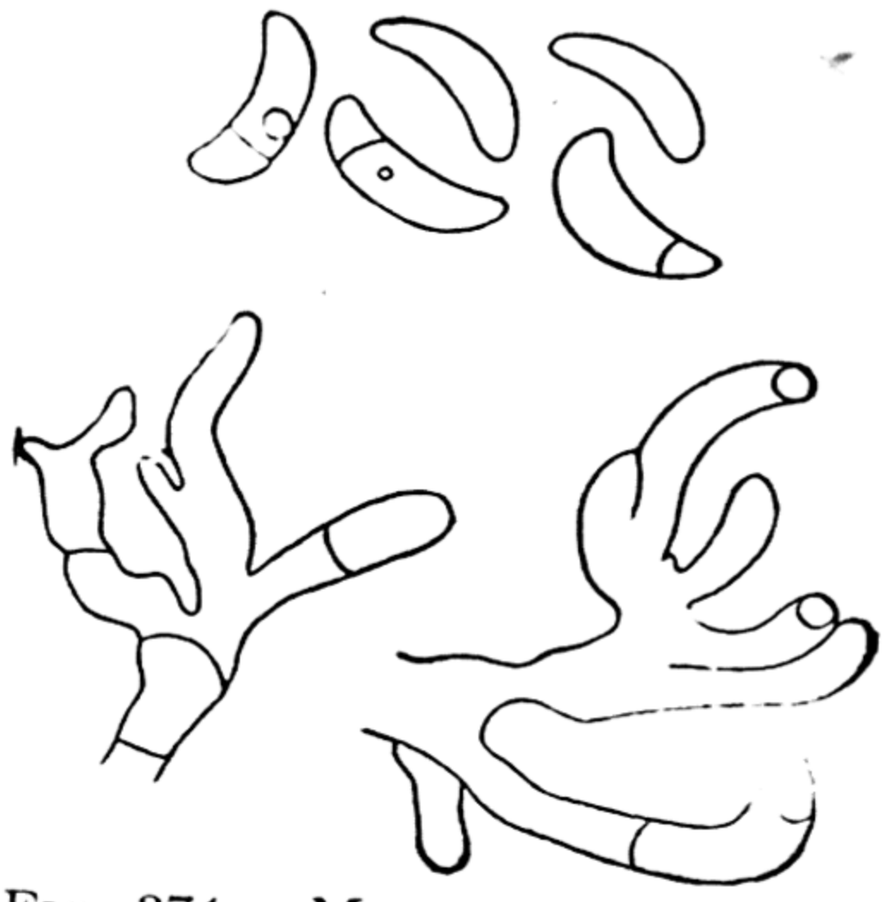


FIG. 374.—Marssonia violæ. Spores and conidiophores. After Jones and Giddings.

100–120 μ, or by confluence larger; conidia abundant, clavate or wedge-shaped, 11–15 x 2.5–3 μ.

The cause of leaf perforations of lettuce.

M. violæ (Pass.) Sacc.[193]

Discoloration of the host slight; acervuli numerous, scattered, small; conidia curved, or straight, 15–18 x 5–6 μ, septum usually excentric.

Small spots are produced on violet leaves.

M. medicaginis Vors. is on alfalfa.

Melanconiaceæ-Phæodidymæ (p. 537)

Conidia dark, 1-septate, ovoid to fusoid.

KEY TO GENERA OF Melanconiaceæ-Phæodidymæ

Conidia solitary
  Conidia muticate. . . . . 1. **Didymosporium,** p. 556.
  Conidia 1 to 3-ciliate at apex. . . . . 2. **Neobarclaya.**
Conidia catenulate, connected by hyaline isthmi. . . . . 3. **Bullaria.**

Didymosporium Nees

Acervuli rounded or elongate, covered, erumpent; conidia elongate or fusoid. A genus of less than twenty species.

D. salicinum Vuill is on poplar.

Melanconiaceæ-Hyalophragmiæ (p. 537)

Conidia hyaline, 2 to several-septate, oblong to fusoid or clavate.

KEY TO GENERA OF Melanconiaceæ-Hyalophragmiæ

Conidia separate
  Conidia muticate
    Conidia oblong or fusoid, masses usually pale. . . . . 1. **Septoglœum,** p. 557.

Conidia long-clavate; masses dark. . . .	2. **Rhopalidium.**
Conidia 1 to several-ciliate, usually at the apex.	3. **Pestalozzina.**
Conidia united at base into a radiate or stellate group.	4. **Prosthemiella.**

Septoglœum Saccardo (p. 556)

Acervuli very small, subepidermal, erumpent, pallid; conidia oblong. Some twenty-five species of leaf parasites.

S. hartigianum Sacc. attacks maple, killing very young twigs.

S. ulmi Fr. is found on elm leaves=Phyllachora ulmi. (?)

S. mori Lev. on mulberry=Mycosphærella mori. (?)

S. cydoniæ (Mont.) Pegl. is on the quince;

S. manihotis Zimm. on manihot in Java.

S. arachidis Rac. is seriously injurious to the peanut in Java.[194]

S. profusum E. & E. is found on Corylus;

S. fraxini Hark. on ash.

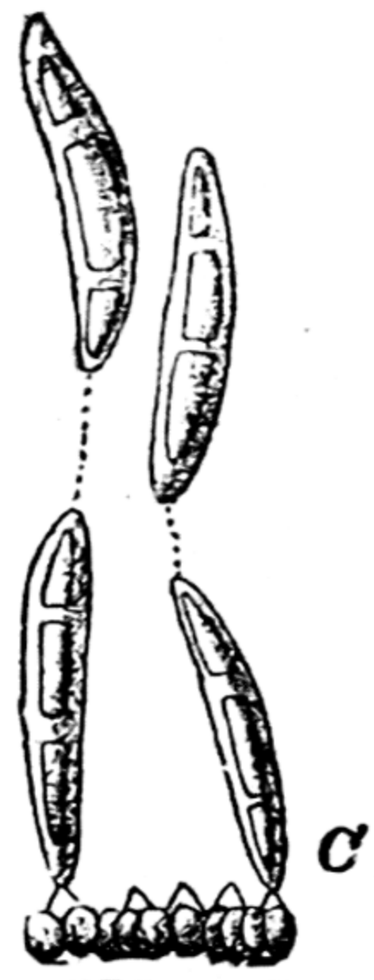


FIG. 375.—Septoglœum acerinum, conidiospores and conidia. After Saccardo.

Melanconiaceæ–Phæophragmiæ (p. 537)

Conidia dark, 2 to several-septate, oblong to cylindric.

KEY TO GENERA OF **Melanconiaceæ-phæophragmiæ.**

Conidia mutic	
Conidia separate, not in chains	
Conidia oblong or elongate, not stellate	
Conidia curved-attenuate, i. e., hyaline-rostrate	
Conidia dark, except the hyaline beak.	1. **Scolecosporium.**
Conidia with 2 inner cells opaque, others clear.	2. **Toxosporium,** p. 558.

Conidia oblong, not rostrate
Conidia cirrhose protruded..... 3. **Stilbospora.**
Conidia not protruded..... 4. **Coryneum,** p. 560.
Conidia stellate-lobed, lobes several-septate..... 5. **Asterosporium**
Conidia in chains
Conidia connected with filiform isthmi 6. **Seiridium.**
Conidia chains without isthmi..... 7. **Seiridiella.**
Conidia ciliate
Conidia ciliate at apex alone
Conidia 1-ciliate..... 8. **Monochætia,** p. 558.
Conidia several-ciliate..... 9. **Pestalozzia,** p. 558.
Conidia 1-ciliate at each end..... 10. **Hyaloceras.**

Toxosporium Vuillemin (p. 557)

Acervuli sublenticular, erumpent, scattered, minute, black; conidia curved, beaked at each end, central cells dark, apical hyaline; conidiophores short, simple.

T. abietinum Vuill.[195] causes drying out of Abies leaves in Europe.

Monochætia Saccardo

As in Pestalozzia except that the conidia bear only a single seta. About sixty species.

M. pachyspora Bubak. is common on Castanea, causing large, circular, dead leaf spots with the acervuli showing in somewhat concentric circles.

Pestalozzia de Notaris

Acervuli subcutaneous, erumpent, discoid or pulvinate, black; conidia elongate, colored or the end cells hyaline, with several hyaline setæ on each end.

A genus of over two hundred species of various habit, some of considerable economic importance.

P. hartigii Tub. causes disease of tree and shrub seedlings in nurseries, constricting the stem just above the soil and resulting in death.

P. funerea Desm.

Acervuli scattered, punctiform, blackish, subepidermal, erumpent; stroma depressed, white; conidia oblong, fusoid, 5-celled, constricted at the septa, the three central cells fuscous, the others hyaline, 22–32 x 6–8 μ, with 2–5 recurved hyaline spines, 10–15 x 0.7–1 μ; conidiophores short, 5–9 x 1–1.5 μ.

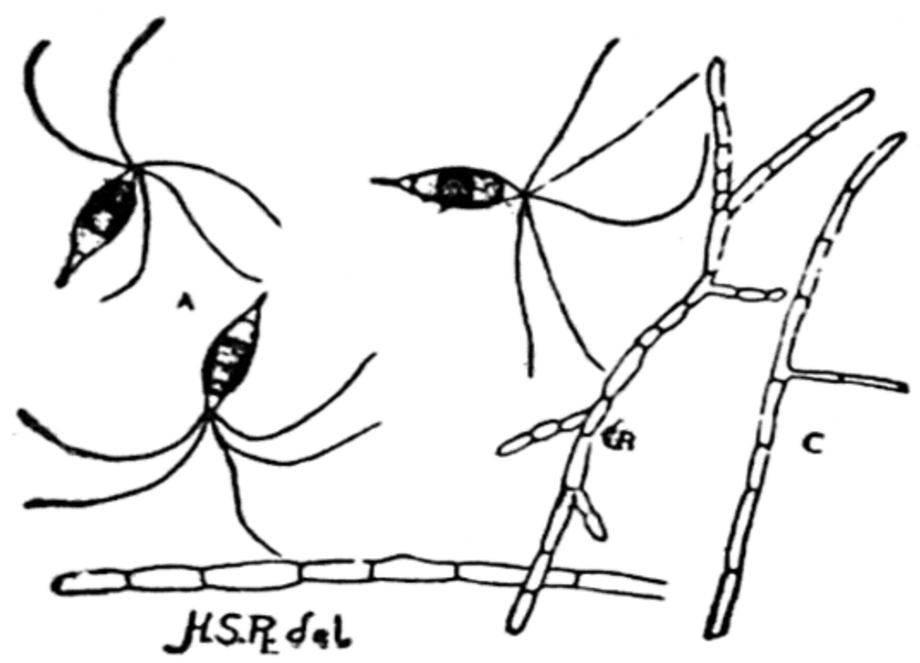


FIG. 376.—P. funerea. A. Spores. B. A young mycelium. C. Hypha of an older mycelium. After Reed.

It is found on various conifers causing disease and is a common saprophyte. In America it causes a stem spot or anthracnose of ginseng,[64] girdling the petioles. The culture characters were studied by Reed.[196]

P. guepini Desm. var. **vaccinii** Sh.[197]

Acervuli minute, punctiform, convex, black, subepidermal, erumpent; conidia elliptic and somewhat unequilateral, about 20 μ long; central cells dark, the two end cells hyaline, the apical cell with 3–4 filiform setæ 22–35 μ long, the basal with a short hyaline appendage, 6–12 μ.

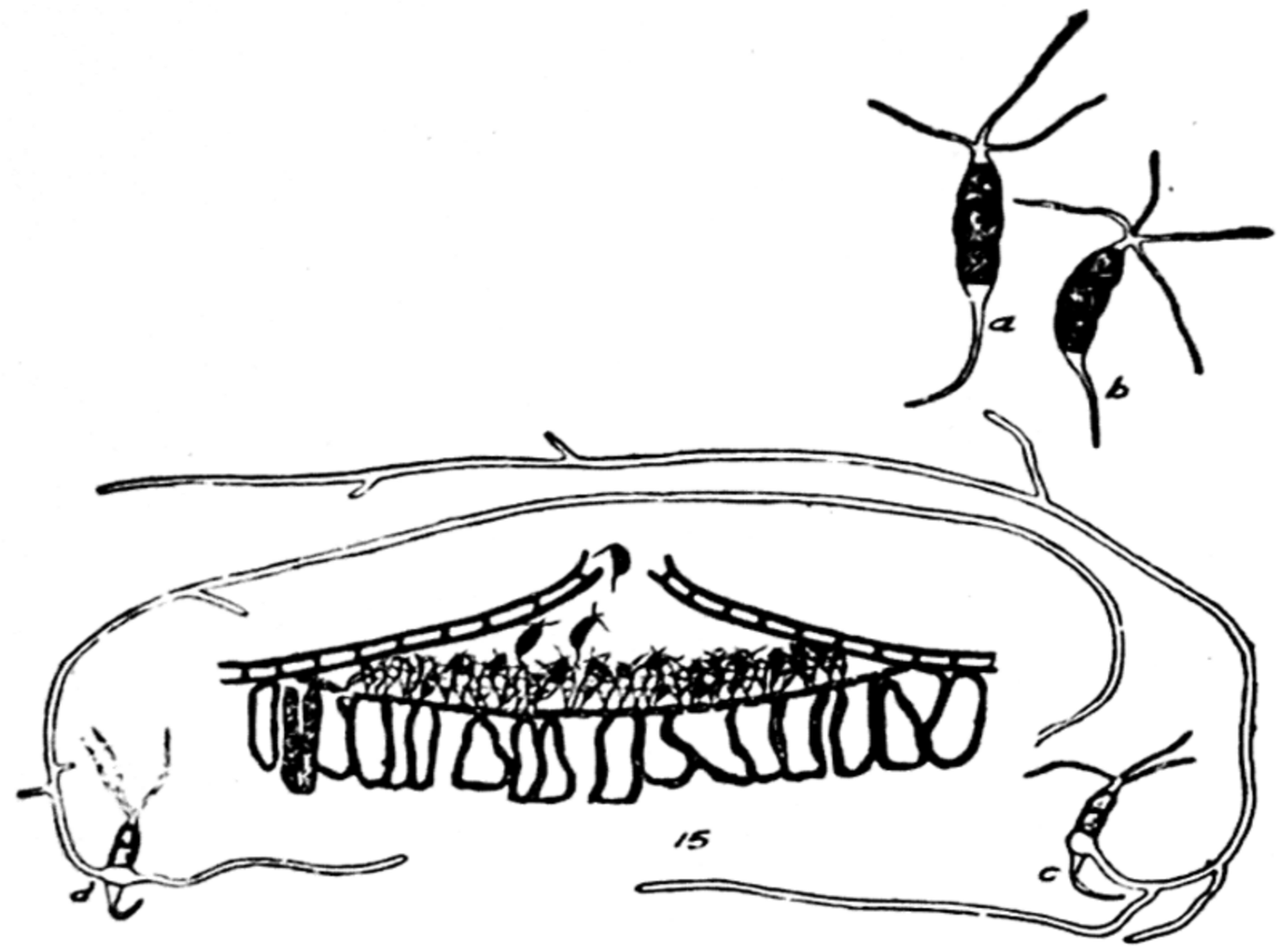


FIG. 377.—Pestalozzia guepini vaccinii; *a*, a conidium having an apical appendage with three branches; *b*, a conidium having an apical appendage with four branches; *c*, a germinating conidium; *d*, a germinating conidium sending out two germ tubes. After Shear.

Common on fallen leaves of cranberries, and associated with rot of the berries. It is common on tea causing a serious disease, also on Camellia, Magnolia, Citrus, Rhododendron.

P. uvicola Speg.[198]

Acervuli globose, lenticular, black, subepidermal, erumpent,

300–400 μ; conidia fusiform, 5-celled, the three median olivaceous-fuscous, the others hyaline, 35 x 8–10 μ, inferior appendage 25–30 x 1 μ, superior group 8–10 x 1 μ.

It is described as the cause of rot of grape berries and of a leaf spot of the vine.

P. aloëa Trinch. occurs on aloë in Italy;
P. clusiæ Griff. & Mont. on Clusia leaves in France;
P. richardiæ Hals. sometimes disfigures calla leaves.
P. tumefaciens Hen. is found on Abies causing galls.
P. gongrogena Temme causes galls and cankers on willow;
P. fuscescens Sor. parasitizes cultivated Corypha;
P. fuscescens var. **sacchari** Wak. is on sugar cane.[59]
On palms occur **P. palmicola** S. & S., **P. palmarum** Cke., and **P. phœnicis** Grev.
P. inquinans C. & Hark is on eucalyptus in California;
P. stictica B. & C. on sycamore and linden;
P. suffocata E. & E. and **P. discosioides** E. & E. on roses.
P. lupini Sor. on Lupinus cotyledons.[200]

Coryneum Nees. (p. 558)

Acervuli discoid or pulvinate, subcutaneous, erumpent, black, compact; conidia oblong to fusoid.

Some seventy-five species.

C. modonia (Sacc.) Griff. & Maub. on chestnut=Melanconis modonia Tul. See p. 281.

C. juniperinum E. on juniper=Exosporium juniperinum.[201]

C. beyerinckii Oud.

Acervuli minute, punctiform, black, gregarious; conidia borne on a parenchymatous pulvinate stroma, stipitate, oblong, ovate, light olivaceous, 3 to many-septate, slightly constricted at the septa or not, cells not all of the same size.

Ascospora beyerinckii is said by Vuillemin to be the ascigerous stage. See p. 236. It is reported as injurious to peaches, causing blight and shot-hole in California [202] and to apricots, cherries and peaches in Africa. It is close to and perhaps identical with Clasterosporium carpophilum.

The acervuli occur as black specks near the centers of the leaf

spots but since diseased tissue soon drops out they are often difficult to find. Bark spots are often sterile. Late in the season spores abound scattered on the surfaces of twigs, especially at rough places, as near leaf scars. Spores near bud scales penetrate them with a mycelium and kill the buds or if on bark they enter the twig and produce dead spots.

C. foliicolum Fuckel.[203]

Spots epiphyllous, ochraceous, indefinite; acervuli punctiform, erumpent; conidia ellipsoid–oblong, 17 x 6–7 μ, 3-septate, con-

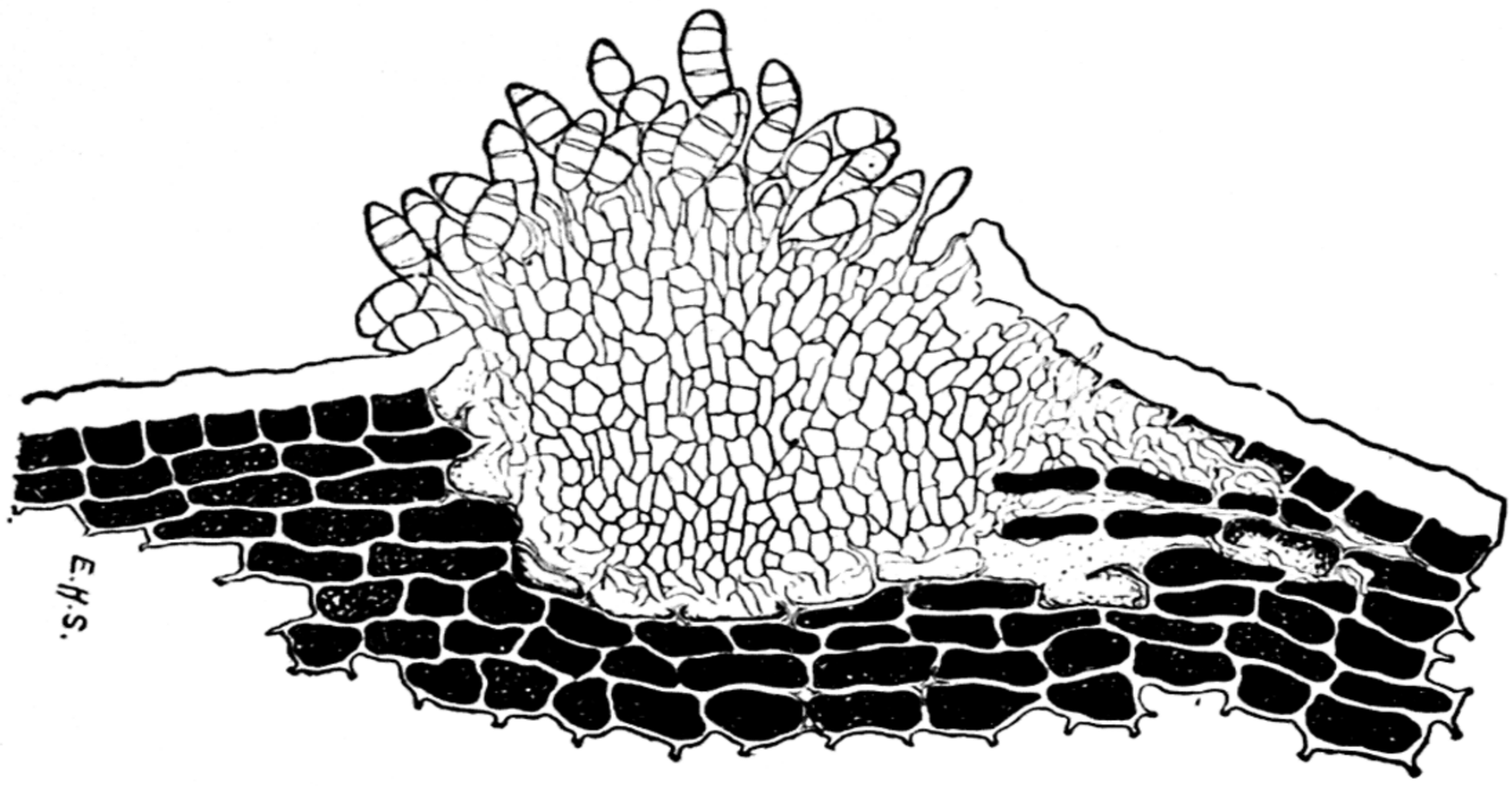


FIG. 378.—C. beijerinckii. Longitudinal section of a pustule. After Smith.

stricted at the septa, olivaceous, lower cell subhyaline, stalk subhyaline, 15–20 x 1.25 μ.

It is present as a saprophyte on apple leaf spots and causes cankers on twigs and branches.

C. camelliæ Mas. is reported on cultivated Camellia.

C. mori Namura causes mulberry twig blight in India.[204]

The **Melanconiaceæ-Hyalodictyæ** and **Melanconiaceæ-Phæodictyæ** containing only three genera have no parasitic species of importance.

Melanconiaceæ–Scolecosporæ (p. 537)

Conidia cylindric, filiform or suballantoid, hyaline, mostly continuous.

KEY TO GENERA OF **Melanconiaceæ-Scolecosporæ**

Conidia allantoid. . . . . 1. **Næmospora.**
Conidia bacillar to filiform
  Conidia fasciculate at the apex of the conidiophores. . . . . 2. **Trichodytes.**
  Conidia solitary
    Masses white or pale, foliicolous; conidia filiform. . . . . 3. **Cylindrosporium,** p. 562.
    Masses gray or dark, usually ramicole; conidia falcate. . . . . 4. **Cryptosporium,** p. 564.
    Masses bright-colored, saprophytic; conidia falcate. . . . . 5. **Libertella,** p. 564.

Cylindrosporium Unger

Acervuli subepidermal, white or pallid, disciform or subeffuse; conidia filiform, continuous, hyaline, straight or curved.

About one hundred species of parasites, several of them of considerable economic importance.

C. mori Berl. on Morus=Mycosphærella morifolia. See p. 249.

C. castanicolum (Desm.) Berl. on Castanea=Mycosphærella maculiformis. See p. 249.

C. padi Karst.[205-210]

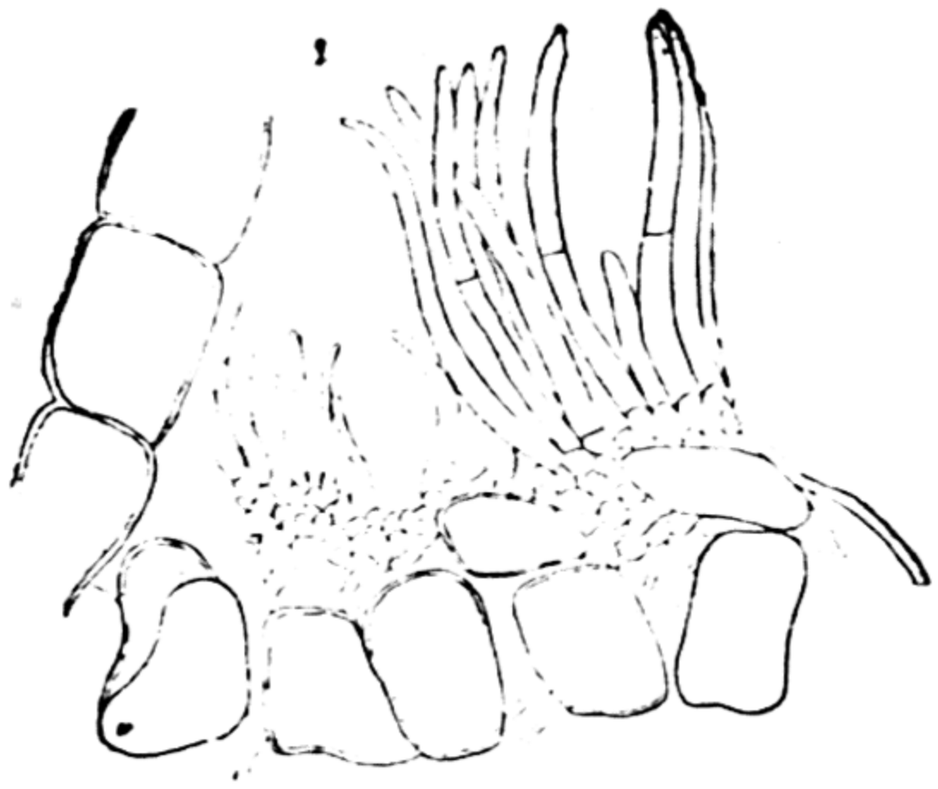


FIG. 379.—C. padi, section of acervulus. After Pammel.

Hypophyllous; spots angular, subfuscous; acervuli subepidermal causing elevations; conidia curved, cylindric, 48-60 x 2 μ; conidiophores minute, produced in great abundance.

This is the cause of the most common, familiar, widespread and destructive shot-hole disease of the cherry and plum. When on the peduncles the fruits are dwarfed and ripen unevenly. The diseased leaf tissue usually falls away, resulting in "shot-holes." Acervuli abound.

Arthur found a Phoma associated with this fungus and later asci in the same pycnidia. He believed these forms all con-

nected but confirmation of such conclusion has not been adduced. Connection with Coccomyces has also been reported.[445]

C. tubeufiana All., also on Prunus is closely like C. padi.

C. pomi Brooks.[211-212]

Acervuli pallid, subeffuse, at first subepidermal, then erumpent; conidia granular, filiform, straight or flexuose, 15–80 x 2–2.5 μ.

It is reported as common from New Hampshire to Virginia and Michigan on apples of almost all varieties, causing small, dry, sunken, brown fruit spots; a disease which had hitherto been referred to a variety of causes. The fungus was studied in numerous culture media and its pathogenicity was proved by inoculations.

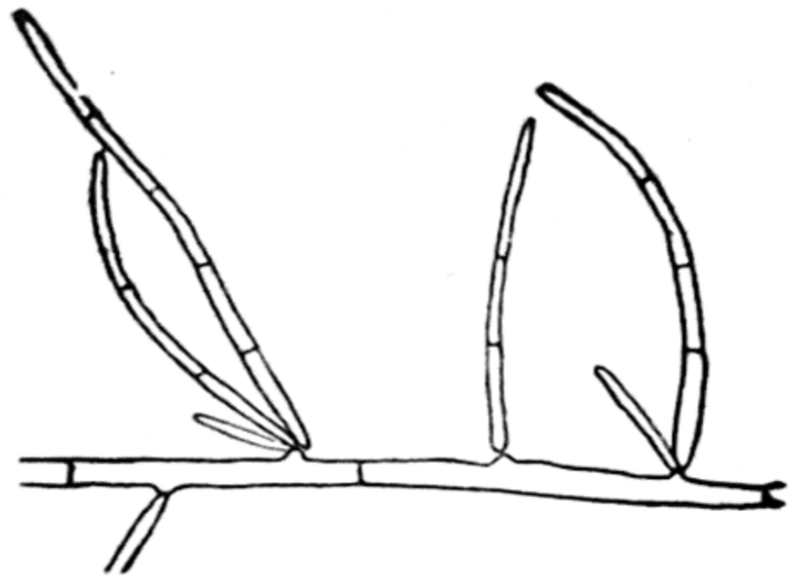


FIG. 380.—Cylindrosporium pomi. Spore formation in artificial cultures. After Brooks.

C. chrysanthemi E. & D.[26]

Spots subindefinite, 1 cm. or more broad, black; acervuli innate, amphigenous, 100–170 μ; conidia fusoid straight, 50–100 x 3–4.5μ.

The fungus causes dark blotches on the leaves of chrysanthemum.

C. clematidis E. & E.

Spots amphigenous, reddish-brown, round or subangular, 1–3 μ; acervuli comparatively few, epiphyllous, immersed, scattered; conidia fusoid-linear, 75–80 x 2.5–3 μ, somewhat curved, exuding in a white mass. It causes leaf spot of Clematis.[17] Later is described a variety **jackmanii** which differs from the species in the acervuli not being confined to the spots, which are less definite, and exuding a black mass of spores which are themselves hyaline.

C. humuli E. & E.

Spots amphigenous, mostly hypophyllous, small, angular, limited by the veinlets, rusty brown; acervuli minute, black, amphigenous; conidia nearly cylindric, granular, 40–50 x 3 μ, oozing out in a white mass.

The cause of leaf spots of hops.[17]

Other parasitic forms are:

C. saccharinum E. & E. on maple;

C. colchici Sacc. on Colchicum;

C. inconspicuum Wint. on lily;

C. orni (Pass.) Pegl. and
C. viridis E. & E. on ash;
C. quercus Sor. on oak;
C. cercosporoides E. & E. on tulip tree.

An unidentified Cylindrosporium is reported from New Jersey and New York as causing spots of tomato with considerable injury.

It is possible that this was in reality Septoria lycopersici.[26, 160]

Cryptosporium Kunze (p. 562)

Acervuli discoid-conic, covered by a peridium, erumpent, forming a pseudo-pycnidium from the substratum; conidia fusoid-falcate, large, continuous, typically stipitate.

Some forty species, chiefly saprophytes.

C. leptostromiforme Kühn forms black stromata on lupine.

C. minimum Lau. is the cause of a rose stem disease and of cankers.

Libertella Desmaziere (p. 562)

Acervuli covered, irregularly and tardily erumpent, conidia filiform, falcate, elongate, continuous.

Some twenty species, chiefly saprophytes.

L. rubra Bon. on Prunus = Polystigma rubrum. See p. 208.

L. ulcerata Mas. causes cankers on fig trees in greenhouses.[214]

Moniliales (p. 479)

The Moniliales differ from the Sphæropsidales in the absence of the pycnidium and from the Melanconiales in their somewhat loose, separate hyphæ, not innate and closely aggregated as in the Melanconiales. There are genera on the boundaries between these orders which are difficult to place, as for example Coryneum, some species of which are often put in Helminthosporium; Vermicularia which sometimes is confounded with Volutella, etc.

The order is one of very great diversity and contains a multitude of forms. Many are only saprophytes while some are aggressive parasites.

Key to Families of **Moniliales**

Hyphæ in more or less loose cottony masses
  Hyphæ and conidia clear or bright colored..... I. **Moniliaceæ,** p. 565.
  Hyphæ and conidia typically both dark; one or the other always dark..... II. **Dematiaceæ,** p. 594.
Hyphæ compactly united or forming a globose to cylindric body which is often stalked
  Hyphal body cylindric to capitate, stalked, i. e., a synnema or corymium..... III. **Stilbaceæ,** p. 632.
  Hyphal body more or less globose, sessile, i. e., a sporodochium..... IV. **Tuberculariaceæ,** p. 638.

Moniliaceæ

Hyphæ hyaline or bright colored, more or less fragile, lax, not cohering in fascicles; conidia concolorous, hyaline or bright colored.

Key to Sections of Moniliaceæ

Conidia globose, ovate, oblong or short-cylindric
  Conidia continous..... 1. **Amerosporæ,** p. 565.
  Conidia two-celled..... 2. **Didymosporæ,** p. 585.
  Conidia three or more-celled..... 3. **Phragmosporæ,** p. 588.
  Conidia muriform..... 4. **Dictyosporæ,** p. 592.
Conidia cylindric, spiral or convolute, usually septate..... 5. **Helicosporæ.**
Conidia of several stellately grouped cells.. 6. **Staurosporæ,** p. 593.

Moniliaceæ-Amerosporæ

Conidia continuous, globose or ovoid to short cylindric.

Key to Groups of Moniliaceæ-Amerosporæ

Hyphæ very short, or obsolete, little different from the conidia
  Conidia not in chains..... 1. **Chromosporieæ,** p. 566.
  Conidia in chains..... 2. **Oösporeæ,** p. 567.

Hyphæ elongate and distinct from the conidia
Conidiophores simple or little branched, apically swollen
Conidia solitary. . . . . **3. Hartigielleæ, p. 570.**
Conidia in heads
Conidia not in chains. . . . . **4. Cephalosporieæ, p. 570.**
Conidia in chains. . . . . **5. Aspergilleæ, p. 572.**
Conidiophores much-branched, conidia not in heads
Conidia borne irregularly on simple or branched but not inflated or verticillate conidiophores. . . . . **6. Botrytideæ, p. 574.**
Conidia borne on verticillately branched conidiophores. . . . . **7. Verticilliæ, p. 583.**
Conidiophores with inflated nodes upon which clusters of conidia are borne **8. Gonatobotrytideæ.**

Chromosporieæ (p. 565)

Hyphæ short or obsolete, conidia not in chains.

Key to Genera of Chromosporieæ

Conidia solitary, at least not capitate
Saprophytic
Hyphæ almost none
Conidia separate. . . . . **1. Chromosporium.**
Conidia joined in twos or threes, not catenulate. . . . . **2. Selenotila.**
Hyphæ very short, branched, septate **3. Coccospora.**
Entomogenous. . . . . **4. Massospora.**
Phytogenous
In fungi
Conidia ovoid, smooth. . . . . **5. Myceliophthora, p. 567.**
Conidia globose, verrucose. . . . . **6. Coccosporella.**
In leaves, hyphæ vermiform-tortuous **7. Ophiocladium, p. 567.**
Conidia capitate; hyphæ lacking; biophilous. . . . . **8. Glomerularia.**

Myceliophthora Costant (p. 566)

Sterile hyphæ creeping, simple or somewhat branched, bearing conidia at the apex; conidia solitary, acrogenous, ovoid.

A single species **M. lutea** Costant. causes disease of cultivated mushrooms in France.[213]

Ophiocladium Cavara (p. 566)

Fertile hyphæ fasciculate, tortuose; conidia acrogenous, elliptic.



FIG. 381.—O. hordei acervulus and spores. After Cavara.

Two species of which one, **O. hordei** Cav., parasitizes barley.

Oösporeæ (p. 565)

Hyphæ short or obsolete, conidia in chains.

KEY TO GENERA OF **Oösporeæ**

Conidial chains arising in the hyphæ	
Conidial branches simple, arcuate.	1. **Malbranchea.**
Conidial branches dichotomous, not arcuate.	2. **Glycophila.**
Conidial chains arising at the apex of the hyphæ	
Conidia globose, elliptic, or ovate	
Conidia all of equal size	
Sterile hyphæ very short or none. . .	3. **Oöspora,** p. 568.
Sterile hyphæ evident, rarely none	
Conidia not connected by an isthmus	
Growing within the substratum	
Haustoria none.	4. **Monilia,** p. 568.
Haustoria present.	5. **Oidiopsis.**
Growing on the surface of living plants.	6. **Oidium,** p. 569.
Conidia connected by an isthmus.	7. **Pæpalopsis.**
Apical conidium larger.	8. **Halobyssus.**
Conidia fusoid, acute at each end.	9. **Fusidium,** p. 568.

Conidia cylindric or cuboid
  Hyphæ nearly obsolete; conidia cylindric. ..... 10. **Cylindrium.**
  Hyphæ distinctly present
    Conidia cylindric. ..... 11. **Polyscytalum.**
    Conidia cuboid ..... 12. **Geotrichum.**

Oöspora Wallroth (p. 567)



FIG. 382.—Oöspora. After Saccardo.

Fertile hyphæ short, sparingly branched, slender; conidia catenulate, globose to ovoid, hyaline or dilute-colored.

Over one hundred species, chiefly saprophytes.

O. scabies Thax.[216, 217, 219-224]

Vegetative hyphæ rarely 1 μ thick, curved irregularly, septate or falsely septate, branching; aërial hyphæ at first white, then grayish, evanescent, breaking up into bacteria-like spores.

Isolation and inoculation in pure culture by Thaxter showed this to be the cause of the common American form of scab of Irish potato, beet, turnip, etc.

O. abietum Oud. causes defoliation of firs in Europe.[215]

Fusidium Link (p. 567)

Hyphæ short, simple, not well differentiated from the conidia which are fusoid, catenulate, acute at the ends, hyaline or dilute-colored. In part = Nectria. See p. 201.

A poorly understood genus of over 50 species.

F. candidum Link. on various trees = Nectria ditissima. See p. 203.

Monilia Persoon (p. 567)

Hyphæ erect, branched, forming a dense mycelial felt, which produces numerous conidiophores; conidia catenulate, hyaline or light-colored, ovate or lemon shaped. In part = Sclerotinia. See p. 136.

Some fifty species.

M. fructigena Pers. on stone and pome fruits=Sclerotinia fructigena. See p. 139.

M. cinerea Bon. on stone and pome fruits=Sclerotinia cinerea. See p. 137.

M. cinerea Bon. on Prunus padus=Sclerotinia padi. See p. 140.

M. cinerea Bon. on Vaccinium oxycoccus=Sclerotinia oxycocci. See p. 140.

M. laxa A. & R. on apricots=Sclerotinia laxa. See p. 137.

M. linhartiana Sacc. on medlars and quinces [17] =Sclerotinia linhartiana. See p. 141.

M. crategi Diedicke on Cratægus =Sclerotinia crategi. See p. 143.

M. seaveri Reade on Prunus =Sclerotinia seaveri.[451, 452] See p. 140.

M. fimicola Cast. & Matr. is a parasite of mushrooms, Clitocybe and Pleurotus.

Oidium Link (p. 567)

On the surface of living leaves; hyphæ branched, white, bearing erect, simple conidiophores with catenulate, ovoid conidia.

About fifty species.

These conidial fungi in the main belong to the Erysiphales though some forms are placed in Oidium which clearly do not belong to that ascigerous order. Salmon states that there are some forty-four apparently Erysiphaceous Oidiums listed; but that twenty-five of these grow on plants known to be the hosts of ascus bearing Erysiphaceæ.

O. fragariæ Harz.=S. humuli. See p. 175.

O. leucoconium Desm.=S. pannosa. See p. 176.

O. balsamii Mont.=E. polygoni. See p. 177.

O. ambrosiæ Thüm.=E. cichoracearum. See p. 178.

O. monilioides Link.=E. graminis. See p. 179.

O. tuckeri Berk.=U. necator. See p. 181.

O. cratægi Grogn.=P. oxyacanthæ. See p. 183.

O. farinosum Cke.=P. leucotricha. See p. 184.

The following may also be mentioned:

O. erysiphoides Fr. on hop, clover, cucumber, etc.;

O. chrysanthemi Rab. on chrysanthemums;

O. mespilinum Thüm on Mespilus;
O. tabaci Thüm on tobacco;
O. verbenæ T. & B. on Verbenas.

O. quercinum Thüm has been reported as the cause of much injury to oaks in Europe since 1907. The identity of the Oidium causing the epidemic is, however, much questioned. By some it is regarded as a stage of Microsphæra alni, by others it is set up under a separate name as **O. alphitoides** G. & M.[225, 226]

Hartigielleæ (p. 566)

One genus, **Hartigiella** Sydow. The species **H. laricis** (Hart.) Syd. causes fall of needles of larch.[359]

Cephalosporieæ (p. 566)

Hyphæ elongate; conidia in heads.

Key to Genera of Cephalosporieæ

Conidia globose or oblong
  Conidia sessile on the head or nearly so
    Fertile hyphæ inflated at apex
      Apical vesicle globose-inflated
        Conidia sessile, not mucus-covered
          Vesicle verrucose or muriculate
            Fertile hyphæ simple. ..... 1. **Œdocephalum.**
            Fertile hyphæ sigmoid, much branched. ..... 2. **Sigmoideomyces.**
          Vesicle hexagonally areolate. ... 3. **Rhopalomyces.**
        Conidia on stalks, mucus-covered. 4. **Gliocephalus.**
      Apical vesicle clavate or lobed
        Vesicle disk-shaped, stellate-lobed..... 5. **Coronella.**
        Vesicle clavate or subpalmate. ... 6. **Buseella.**
    Fertile hyphæ not inflated at apex
      Conidial head covered with mucus
        Fertile hyphæ simple. ..... 7. **Hyalopus.**
        Fertile hyphæ with verticillate branches at tip..... 8. **Gliobotrys.**
      Conidial head without mucus
    Fertile hyphæ with one head
      Conidia not separating. ..... 9. **Papulospora.**

Conidia separating
Head elongate. . . . . 10. **Doratomyces.**
Head globose or slightly clavate
Sterile hyphæ scanty. . . . . 11. **Haplotrichum.**
Sterile hyphæ long, decumbent. . . . . 12. **Cephalosporium,** p. 571.
Fertile hyphæ with 2 to several heads
Conidia upright on verticillate conidiophores. . . . . 13. **Cœmansiella.**
Conidia in more definite heads
Fertile hyphæ simple, with 3 to several heads of conidia on spines. . . . . 14. **Botryosporium,** p. 571.
Fertile hyphæ several times 2 to 3-fid. . . . . 15. **Trichoderma.**
Conidia borne on little stalks or sterigmata
Fertile hyphæ simple. . . . . 16. **Corethropsis.**
Fertile hyphæ verticillate branched. . 17. **Spicularia.**
Conidia short cylindric
Conidia without mucus. . . . . 18. **Cylindrocephalum.**
Conidia covered with mucus. . . . . 19. **Acontium.**

Cephalosporium Corda

Hyphæ creeping, conidiophores short, erect, not apically swollen. Conidia spherical or ovate, hyaline or slightly colored.

The small spored condial forms often associated with Fusarium (microconidia) belong to this form-genus.

Botryosporium Corda

Hyphæ assurgent, simple or forked, elongate, irregularly laterally branched; fertile branches simple, with three or more short apical branches which end in heads of conidia; conidia globose to ovate.

A genus of only about ten species.

B. diffusum (Grev.) Cda. has been reported as parasitic on Casuarina;

B. pulchrum Cda. on wheat and radish.

B. longibrachiatum (Oud.) Maire on various green-house plants.

Aspergilleæ (p. 566)

Hyphæ well developed; conidia in heads, catenulate.

KEY TO GENERA OF **Aspergilleæ**

Fertile hyphæ inflated at apex
  Fertile hyphæ simple or nearly so
    Sterigmata of apical vesicle none or simple
      Cōnidia terminal on sterigmata. . . . . 1. **Aspergillus,** p. 572.
      Conidia lateral and terminal on sterigmata . . . . . 2. **Dimargaris.**
    Sterigmata verticillately branched. . . . 3. **Sterigmatocystis,** p. 573.
  Fertile hyphæ dichotomous, branches curved. . . . . 4. **Dispira.**
Fertile hyphæ little or not at all inflated
  Fertile hyphæ verticillately branched at tip
    Tips equally verticillate; conidia doliform. . . . . 5. **Amblyosporium.**
    Tips unequally verticillate; conidia globoid
      Conidia without mucus
        Conidiophores slender. . . . . 6. **Penicillium,** p. 573.
        Conidiophores swollen, conidia enclosed in mucus. . . . . 7. **Gliodcladium,** p. 574.
Fertile hyphæ not verticillate at tip. . . . . 8. **Briarea.**

Aspergillus (Micheli) Link

Hyphæ effused, creeping; conidiophores erect, simple, capitate; conidia catenulate; sterigmata none or indistinguishable from the conidia.

The conidia are often found, the asci but rarely.

A. fumigatus Brizi, is held responsible by Brizi[227] for pathological changes in wheat seed which rendered them incapable of germination.

A. ficuum (Hen.) Weh. and **A. phœnicis** (Cda.) Lind. occur on figs.

Sterigmatocystis Cramer (p. 572)

As in Aspergillus but with the sterigmata branched in whorls at the apex.

S. niger Van Tiegh.

Hyphæ slender, conidiophores erect, 800–1000 x 11–16 μ, thick-walled, hyaline or dark above, the apical globose swelling black; basidia 40 μ long, radiately arranged, sterigmata obclavate, 8–10 μ long; conidia globose, 3.4–4.5 μ, minutely verrucose, violet-brown, catenulate. On tobacco.



FIG. 383.—B. pulchrum. After Corda.



FIG. 384.—Aspergillus. From Strassburger et al., Text Book of Botany.

S. ficuum (Reich.) Hen.

Conidia globose, 3.8 μ, dark violet, thick-walled, smooth.

In the fruits of figs in Asia Minor and United States.

S. luteo-nigra Lutz. is injurious to cacao in the tropics.

Penicillium Link (p. 572)

Hyphæ creeping; conidiophores erect, apically irregularly verticillate-penicillately branched; conidia catenulate, spherical, or

elliptical, hyaline or variously colored. For the ascigerous stage see page 167.

The conidial stages of many Penicilliums have been given searching investigation and comparative study by Thom.[228]

P. glaucum Lk.

Hyphæ effused, creeping, septate, interwoven, white, conidiophores penicillate, branches single or in pairs, erect, forked; conidia globose to broadly elliptic, smooth, hyaline, with a tinge of green, 4 μ.

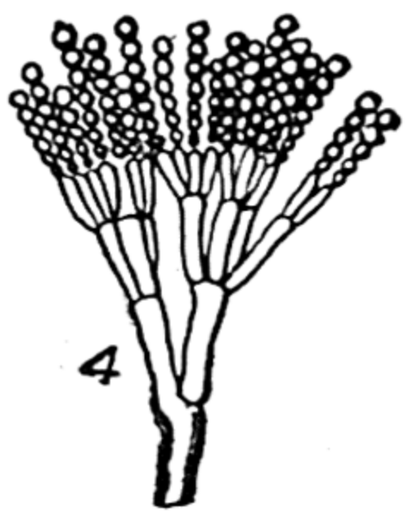


FIG. 385.—Penicillium. After Brefeld.

It is the cause of rot of ripe oranges, lemons, apples, etc.

P. italicum Weh. is described as a wound parasite on oranges by Massee.[22] It is very similar in appearance to P. glaucum but a little greener; conidia elliptic-oblong, 7-9 x 4 μ.

P. digitatum (Fr.) Sacc.

Similar to the preceding species in habit but the conidia are white in mass, 4–6 μ. Often associated with, and similar in effects to P. glaucum.

P. olivaceum Weh. is found on citrous fruits;

P. luteum Zuk. on apple.

An undetermined species is reported as the cause of a white dry rot of sweet potatoes.[330]

Various other species of the genus occur on fruits and vegetables causing their decay.

Gliocladium Corda (p. 572)

Hyphæ effused, spreading; conidiophores and conidia as in Penicillium but the conidia surrounded by a mass of mucus.

A genus of only about ten species.

G agaricinum C. &. M. arrests growth and breaks the pilei of mushrooms.

Botrytideæ (p. 566)

Conidiophores elongate, simple or branched but not inflated, and the branches not verticillate; conidia borne variously, globose or ovate to elliptic.

KEY TO GENERA OF **Botrytideæ**

Conidia smooth or scarcely roughened
Saprophytic or apparently so, often real parasites
Conidia typically pleurogynous
Fertile hyphæ 2 to several-furcate. . . 1. **Haplaria.**
Fertile hyphæ simple or nearly so
Conidia globose or ellipsoid. . . . . 2. **Acladium.**
Conidia short cylindric. . . . . 3. **Cylindrotrichum.**
Conidia acrogenous or pleurogynous
Some intermediate joints of the hyphæ swollen and denticulate, conidia-bearing. . . . . 4. **Physospora.**
Intermediate joints equal
Conidia-bearing hyphæ of two sorts, the upright alone denticulate 5. **Blastomyces.**
Conidia-bearing hyphæ of one sort
Fertile hyphæ simple or nearly so
Hyphæ not denticulate; conidia solitary
Hyphæ forming a crust-like stratum. . . . . 6. **Hyphoderma.**
Hyphæ loose, cobwebby. . . 7. **Acremonium**, p. 577.
Hyphæ denticulate; conidia usually grouped
Hyphæ everywhere denticulate, bearing conidia only at tip. . . . . 8. **Xenopus.**
Hyphæ denticulate or proliferous at tip alone
Apex denticulate, many-spored. . . . . 9. **Rhinotrichum.**
Apex inflated-ampulliform, 1-spored. . . . . 10. **Olpitrichum**
Fertile hyphæ branched
Conidia globose to ovoid
Both sterile and fertile hyphæ procumbent
Sterile hyphæ intracellular. . . . . 11. **Hartigiella.**

Sterile hyphæ superficial
Fertile hyphæ vaguely branched
Conidia acro-pleurogynous..... 12. **Sporotrichum,** p. 577.
Conidia on a one-sided sympodium..... 13. **Monopodium.**
Fertile hyphæ dichotomous; conidia acrogenous on spine-like branches..... 14. **Langloisula.**
Fertile hyphæ erect or ascending
Conidia solitary acrogenous
Fertile hyphæ spiny-branched at apex. 15. **Plectothrix.**
Fertile hyphæ not spiny-branched... 16. **Monosporium.**
Conidia loosely grouped about the apex
Conidia not involved in mucus
Conidia on inflated muriculate apices 17. **Phymatotrichum.**
Apices not muriculate or inflated. 18. **Botrytis,** p. 578.
Conidia involved in mucus..... 19. **Tolypomyria.**
Conidia fusoid to cylindric
Fertile hyphæ mostly procumbent..... 20. **Sporotrichella.**
Fertile hyphæ erect or ascending
Conidia fusoid on the upper side of curved branches..... 21. **Martensella.**
Conida acrogenous
Conidia-bearing branches terete... 22. **Cylindrophora.**

Conidia-bearing branches ellipsoid	23. **Cylindrodendrum.**
Biogenous	
Conidia smooth	
Catenulate	24. **Ovularia,** p. 582.
Solitary	25. **Ovulariopsis,** p. 582.
Conidia densely spiny	26. **Ramulaspera.**
Conidia muricate or tuberculose-stellate	
Conidia globose	
Conidia merely muricate	
Hyphæ loose, cobwebby	27. **Sepedonium.**
Hyphæ woven into a subgelatinous pellicle	28. **Pellicularia,** p. 382.
Conidia setose at apex as well as muricate	29. **Chætoconidium.**
Conidia tuberculose-stellate	30. **Asterophora.**

Acremonium Link (p. 575)

Hyphæ subsimple, procumbent; conidiophores simple, short; conidia solitary, hyaline or light colored, oval to ellipsoid.

A genus of some ten species.

An undetermined species is recorded by Humphrey [27, 125] as causing disease of cucumbers in Massachusetts.



FIG. 386.—Acremonium. After Saccardo.

Sporotrichum Link (p. 576)

Hyphæ widely spreading, much branched; conidiophores simple, short; conidia solitary or in groups on separate sterigmata, ovoid or subglobose.

Over one hundred twenty-five species are described, most of which are saprophytes.

S. poæ Pk.

Hyphæ creeping, interwoven, branched, continuous or sparingly septate, variable in thickness, 2.5–6 μ, hyaline, forming a loose cottony stratum; conidia of two kinds; microconidia, globose or broadly ovate, 4–12 μ; macroconidia abundant, elongate elliptic to ovate elliptic, 1 rarely 2–septate, about three or four times as large as the microconidia.

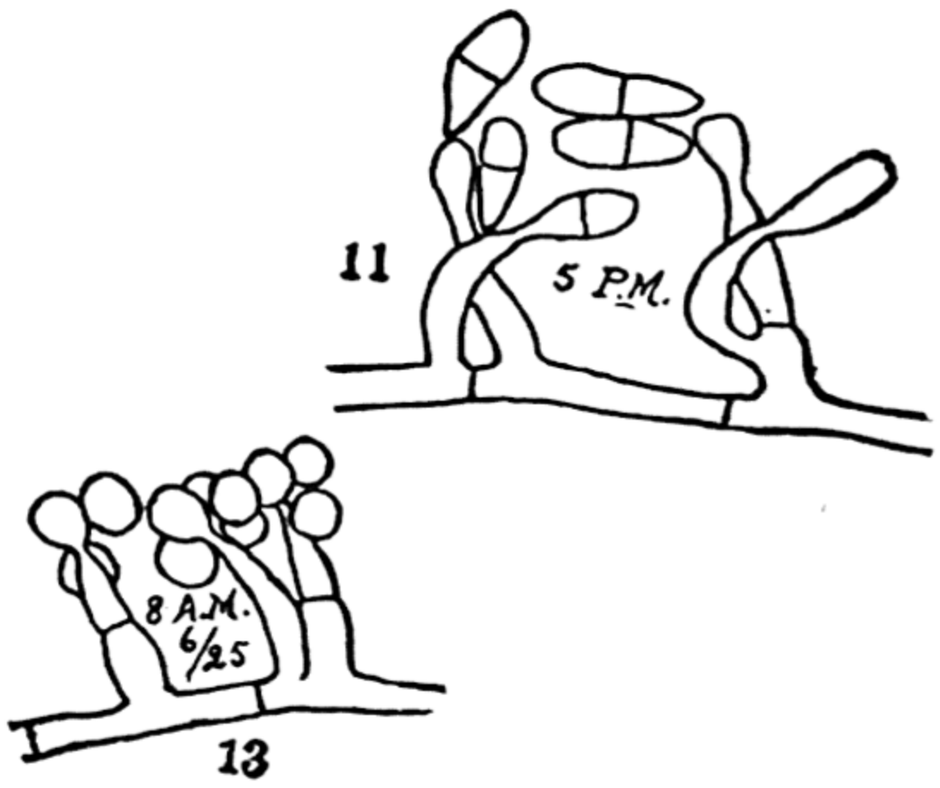


FIG. 387.—S. poæ. 11, Hypha bearing conidiophores and macroconidia. 13, Hypha bearing conidiophores and microconidia. After Heald.

The form is an atypical one in that it produces two kinds of spores; one kind which is usually septate

Heald [229] also Stewart and Hodgkiss [230] have described it as the cause of bud rot of carnations, while the latter authors also mention it in connection with a disease known as "silver top" of June grass in which the panicles wither as they expand, though the authors express doubt as to its actual causal relation to the disease. A mite appears to be the carrier of the spores. Cultural studies and cross-inoculation showed the fungus form on the two hosts to be identical.

Botrytis (Micheli) Link (p. 576)

Hyphæ creeping; conidiophores simple or more or less markedly dendritic branched, erect, branches various, thin and apically pointed, thick and obtuse or cristate; conidia variously grouped at the apex of the branches, never in true heads, continuous, globose, elliptic or oblong, hyaline or light colored.

In part =Sclerotinia. See p. 136.

A genus of some two hundred or more species, several of them of great economic importance.

This form-genus contains many parasites on various hosts. In some instances they are known to include ascigerous stages, (Sclerotinia), in their life cycle; in others no such relation is known, though it has often been assumed on quite untenable grounds. Specific limitations are but poorly understood and the relations between the various forms and between these forms and the ascigerous stages are in a state of much confusion c. f. (p. 137). In some instances the same conidial stage is claimed by different investigators as belonging to two distinct ascigerous species, a manifest impossibility, (e. g., S. fuckeliana and S. libertiana with B. cinerea.)

The more prominent forms as described are given below, recognizing that some of them may be co-specific.

B. cinerea Pers.[231–243]

Hyphæ slender, constricted at septa, gregarious, simple or sparsely branched, erect, cinereous, conidia globose, pale.

A form which occurs on the grape is usually referred to S. fuckeliana though there is not entire agreement on this point. On the grape the Botrytis develops its mycelium in the berries and produces dense tufts of conidia over their surfaces. The sclerotia form within the fruits. Leaves and canes are also affected. (see p. 140).

On the lily Ward[233] in a classic study demonstrated the parasitism of the fungus showing its action to be dependent upon toxins and enzymes. The type in this case deviated somewhat from the usual B. cinerea in that its spores were a little larger than is usual, but it nevertheless seemed to be this species. No ascigerous stage was found.

On Cyclamen and Primula Wehmer[236] reports a similar case.[240] The fungus has also often been reported on the cultivated geranium.

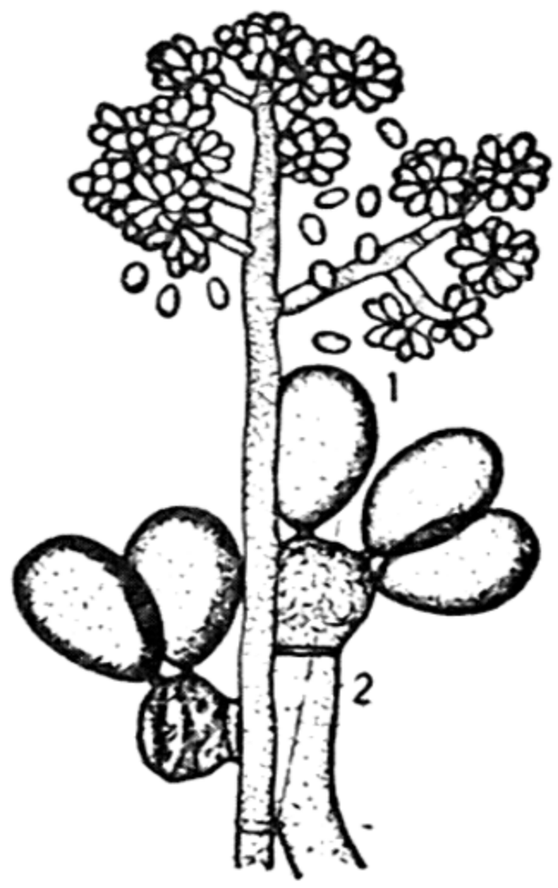


FIG. 388.—B. cinerea. After Smith.

On lettuce Humphrey,[237] Jones,[238] Bailey,[239] and many others have reported a greyish mold on the leaves due to a Botrytis which is often cited as B. cinerea though it appears to form no ascigerous stage. The affected part of the leaf collapses and is covered with a conspicuous growth of the conidiophores and conidia. Small sclerotia are produced in considerable abundance when on artificial media but they, on germination, bear clusters, dense bushy tufts, of conidiophores. That this form on lettuce ever produces ascophores is doubtful.

Smith describes a case in which linden stems beginning at the ground were parasitized by B. cinerea. The bark appeared to be first affected and sclerotia formed in the cortical parenchyma. Similar cases are on record regarding the rose, various conifers, grape (Brizi) Aesculus, Prunus. In all of these cases the Botrytis seems to be B. cinerea and without ascophores.

Numerous studies [241] of the power of B. cinerea to infect growing tissue have been made with the conclusion that it is a weak parasite and that to become aggressively parasitic it must first develop a vigorous mycelium saprophytically. Attempts to immunize plants against its attack have been made with partial success.[242]

Extensive studies of the condition of sclerotia and conidia formation by B. cinerea (from grape) were made by Reidemeister.[243] He concludes that sclerotia form on all media favorable to growth of the fungus. They are on an average 5–8 mm. in diameter, smaller under conditions of poor nutriment, high osmotic pressure or strong transpiration. They are often found in concentric rings and their formation is induced by the presence of various agents which inhibit growth. Conidia are formed under condition of energetic transpiration and on media of high osmotic tension. Conidia and sclerotia vary inversely in production. Appressoria develop on all media where sclerotia grow and are favored by substances which inhibit growth. Conidia are suppressed by conditions favoring the formation of appressoria.

B. deprædens Cke. is a pest of the sycamore.

B. fascicularis (Cda.) Sacc.[18]

Cespitose, minute, brownish; hyphæ erect, fasciculate, flexuose, brown, or semi-pellucid, branches hyaline; conidia in subglobose, white heads, oblong, large.

A mold of egg-plants is attributed to this fungus by Halsted.

An undetermined Botrytis is reported on carnation by Atkinson and another on Ribes.[244]

B. parasitica Cav.

Hyphæ cinereous, sparse, erect, inflated at base; conidia ovate, large, short-pedicillate, on short branches, heads umbellate, hyaline or dilute, cinereous, 16–20 x 10–13 μ.

This is said by Halsted [21] to be the form found on lilies, particularly the bulbs, in New Jersey. It was first reported by Cavara in Italy and is widespread and destructive.

B. pœoniæ Oud. [23, 245, 246]

Mycelium in the parenchyma of the host, hyphæ erect, 0.25–1 mm. high, protruding through the stomata, branches spirally

arranged, simple, or branched; conidia, numerous, in heads 12–15 μ across, oblong or ovate-oblong, 16–18 x 7–7.5 μ, hyaline or dilute colored.

It is reported as the cause of considerable injury to peonies in different parts of the United States. The greenish-black flat sclerotia are found inside the stems.

It is mentioned by Bos [245] as parasitic on young peony stems and on lily-of-the-valley and lilac.

B. longibrachiata Oud.[222, 248]

White, sparse, cespitose, 1.5–2 mm. high; mycelium creeping, branched; fertile hyphæ, verticillate, hyaline, much branched and apically inflated; conidia numerous, hyaline, oval, 4.5–5.5 x 2.5 μ.

It was reported by Thaxter [222] as the cause of stem rot of tobacco in the curing house. The affected stems are covered with white velvety patches of mycelium which soon spread to the veins.

The same fungus is reported by Aderhold on ferns.[249]

This is perhaps a form of B. cinerea.

B. douglassi Tub. on fir may be B. cinerea and =Sclerotinia fuckeliana. See p. 140.

B. citricola Brizi, closely related to B. cinerea, attacks oranges and citrus fruits resulting in mummies.

B. diospiri Brizi attacks the persimmon fruit near time of ripening and prevents maturity.

B. patula S. & Ber.[250]

Cespitose, minute, greyish-white, spots cottony, suborbicular; fertile hyphæ assurgent, continuous, filiform, branching, paniculate; conidia large, globose or globose-elliptic. 30 μ in diameter, light yellow. On raspberries.

B. infestans (Hazsl.) Sacc. is common on hemp in Europe. It sometimes is associated with Sclerotinia libertiana which has led some to assume its connection with that fungus; but no such genetic relation is probable.

B. galanthina Lud. occurs on snowdrops. It is said to belong to Sclerotinia galanthina, see p. 141, but the asci have not been seen.

Undetermined species are reported on carnations, Ribes and mangold.[251]

Ovularia Saccardo (p. 577)

Hyphæ, simple, or sparingly branched, erect, apically simple or dendritically branched; conidia globose or ovoid, solitary, rarely in short chains.



FIG. 389.—Ovularia. After Sorakin.

Over seventy-five species, all parasites.

O. necans (Pass.) Sacc. produces spots on quince leaves in Italy and France;

O. canægricola Hen. on economic species of Rumex;

O. armoraciæ Fcl. on horseradish;

O. interstitialis B. & Br. and **O. primulana** Thüm. on primrose leaves;

O. viciæ (Frank.) Sacc. on Vicia;

O. corcellensis Sacc. on Primula;

O. alnicola Cke. on Alnus;

O. rosea Fcl. on willow;

O. villiana Mag. on lemons;

O. syringæ Berk. on lilac.

O. citri B. & F. causes the white rust of lemons in Sicily.[252]

A lemon disease in Australia has been credited by McAlpine [253] to **O. citri** McAlpine.

O. medicaginis Br. & Cav. is on alfalfa;

O. exigua (W. Sm.) Sacc. on clover.

Ovulariopsis Patouillard & Hariot (p. 577)

Similar to Ovularia, except in the solitary, acrogenous, subclavate conidia.

Sterile hyphæ creeping, conidiophores erect, simple, septate, at apex with a single 1-celled hyaline, subclavate conidium.

A small genus of leaf parasites, in part conidia of the Erysiphaceæ (Phyllactinia). See p. 187.

O. ulmorica Del. causes a mildew of mulberries.[254]

Pellicularia Cooke (p. 577)

Hyphæ creeping, branched, septate, in a subgelatinous pellicle, conidia sessile.

A single species. **P. koleroga** Cke. causes a coffee leaf rot in India and has been reported by Fawcett [255] as causing serious leaf blight of the same host in the West Indies.

Verticillieæ (p. 566)

Conidia acrogenous, on verticillate branches of the conidiophore.

Key to Genera of **Verticillieæ**

Conidia solitary or loosely grouped, not in chains
- Conidia-bearing branches very short, ampulliform. ..... 1. **Pachybasium.**
- Conidia-bearing branches terete or longer
  - Conidia globose to ovoid
    - Tips of branches clavate, in twos rectangularly. ..... 2. **Verticilliopsis,** p. 584.
    - Tips of branches not as above
      - Conidia conglutinate into a stratum. ..... 3. **Corymbomyces,** p. 584.
      - Conidia not conglutinate
        - Conidia separating readily from the tips. ..... 4. **Verticillium,** p. 584.
        - Conidia separating with difficulty from the tips. ..... 5. **Cladobotyrum.**
  - Conidia cylindric or elongate
    - Conidia-bearing branches or sporophores 1-spored
      - Sporophores straight. ..... 6. **Acrocylindrium.**
      - Sporophores uncinate. ..... 7. **Uncigera.**
    - Sporophores several-spored
      - Sporophore inflated verrucose at apex. ..... 8. **Calcarisporium.**
      - Sporophore incurved, with seriate conidia below. ..... 9. **Coëmansia.**

Conidia capitate or densely spicate, not in chains
- Conidia sessile
  - Conidia capitate, involved in mucus
    - Fertile hyphæ smooth ..... 10. **Acrostalagmus,** p. 584.
    - Fertile hyphæ asperate. ..... 11. **Glœosphæra.**

Conidia densely spirally spicate at apices..... 12. **Clonostachys.**
Conidia on small stalks..... 13. **Sceptromyces.**
Conidia in chains..... 14. **Spicaria, p. 585.**

Verticillium Nees (p. 583)

Hyphæ creeping; conidiophores erect, verticellately branched; conidia borne singly at the apex of the branchlets, globose-ovoid, hyaline or light colored.

A genus of some seventy-five species, which are in the main conidia of various species of Hypocreales. See p. 196.

V. albo-atrum McA. is a weak wound parasite of the potato.

Verticilliopsis Cast (p. 583)

Fertile hyphæ with verticillate branches, 2 or 3 at each node; fertile branches clavate; conidia in heads, surrounded by a slime. A monotypic genus.

V. infestans Cast. infects mushrooms in culture.

Corymbomyces Appel & Strunk (p. 583)

Sterile hyphæ creeping; fertile hyphæ erect, septate, dichotomous corymbose; conidia ellipsoid, clustered in gelatinous masses at the apex of the branches.

A single species, **C. albus** Appel & Strunk. on cacao in Africa.

Acrostalagmus Corda (p. 583)

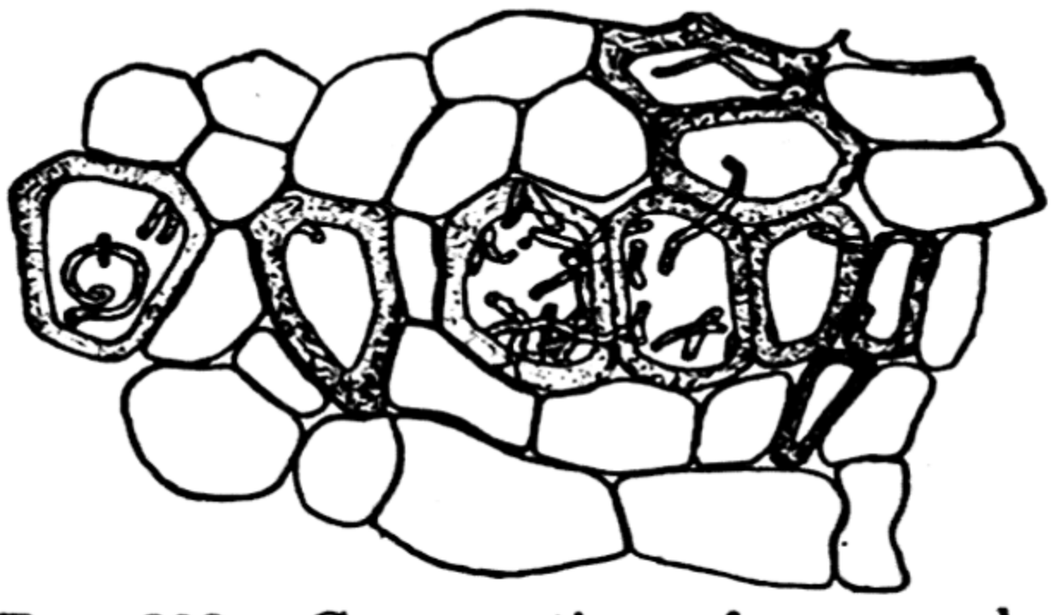


FIG. 390.—Cross-section of a vascular bundle. Acrostalagmus threads in the vessels. After Van Hook.

Hyphæ creeping; conidiophores erect, septate, richly verticillately branched; conidia borne in slimy heads on the enlarged end of the secondary branches.

About fifteen species.

A. albus Preu.

Hyphæ cespitose, effuse, slender, subangular, continuous or septate, conidiophores, 200–220 x 1.7–2 μ, erect; fertile branches continuous, straight or curved; conidia in spherical heads, 9–10 μ

in diameter, numerous, minute, elliptic oblong, 3.3–3.4 x 1–1.5 μ, hyaline.

It causes a wilt of ginseng. The vascular bundles are yellowed and the ducts plugged by the mycelium. Entrance is apparently through the leaf scars. The fungus was isolated by Van Hook [256] and cultural studies made. In a later article Rankin [257] has discussed what appears to be this fungus under the name A. panax.

A. vilmorinii Gue.[258, 259] causes a disease of China asters and a species closely related, one of cacao fruits.

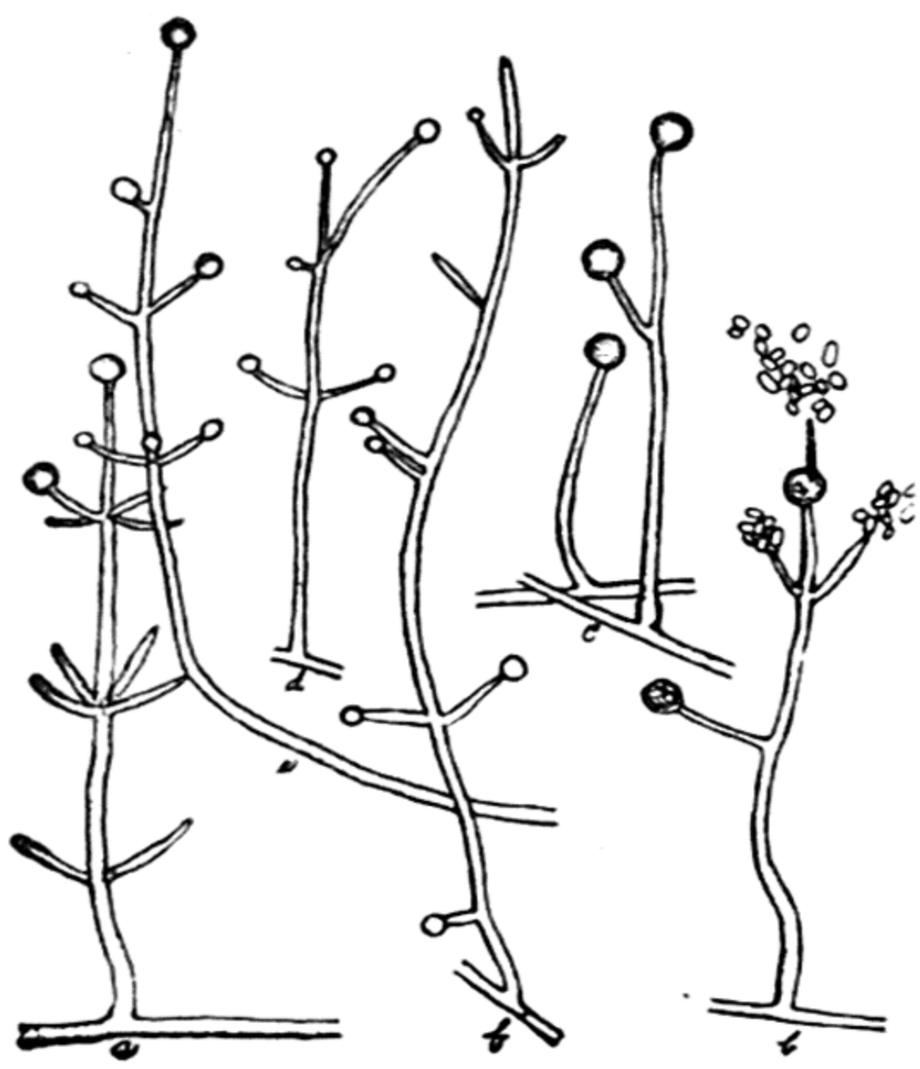


FIG. 391.—Spore-bearing stalks of Acrostalagmus albus. The spores are borne in heads and are held together at first by a coat of slime. After Van Hook.

Spicaria Harz (p. 584)

Hyphæ creeping; conidiophores erect, much branched; conidia apical, catenulate, ovate or elongate, hyaline or dilute colored.

About ten species.

S. solani Hart. is said to produce effects on the potato much like those of Fusarium solani.[456]

S. colorans v. Hall, the cause of cacao cankers is probably a conidial stage of **Calonectria cremea**. See p. 205.

Moniliaceæ-Didymosporeæ (p. 565)

Conidia hyaline, or bright colored, 1-septate, ovoid oblong or short fusoid.

KEY TO GENERA OF **Moniliaceæ-Didymosporeæ.**

Conidia not in chains
  Saprophytic or on fungi
    Conidia smooth
      Fertile hyphæ simple or nearly so
        Hyphæ inflated at apex or joints
          Hyphæ denticulate, inflated at apex; conidia fusoid. . . . . 1. **Diplorhinotrichum.**

Hyphæ inflated at both apex and joints.	2. **Arthrobotrys.**
Hyphæ not inflated	
Conidia spirally pleurogynous	3. **Haplariopsis.**
Conidia solitary, acrogenous or capitate	
Conidia capitate at apex. . .	4. **Cephalothecium,** p. 586.
Conidia solitary at apex	
Fertile hyphæ long.	5. **Trichothecium.**
Fertile hyphæ very short	6. **Didymopsis.**
Fertile hyphæ branched	
Branching irregular.	7. **Diplosporium.**
Branching verticillate.	8. **Diplocladium.**
Branching dichotomous; sterigmata subternate.	9. **Cylindrocladium.**
Conidia echinulate; conidial cells unequal.	10. **Mycogone,** p. 587.
Biophilous	
Conidia obliquely beaked.	11. **Rhynchosporium,** p. 587.
Conidia not beaked	
Hyphæ mostly simple, not spirally twisted.	12. **Didymaria,** p. 587.
Hyphæ simple, spirally twisted. . .	13. **Bostrichonema.**
Conidia catenulate	
Fertile hyphæ simple, short.	14. **Hormiactis.**
Fertile hyphæ verticillately branched. .	15. **Didymocladium.**

Cephalothecium Corda

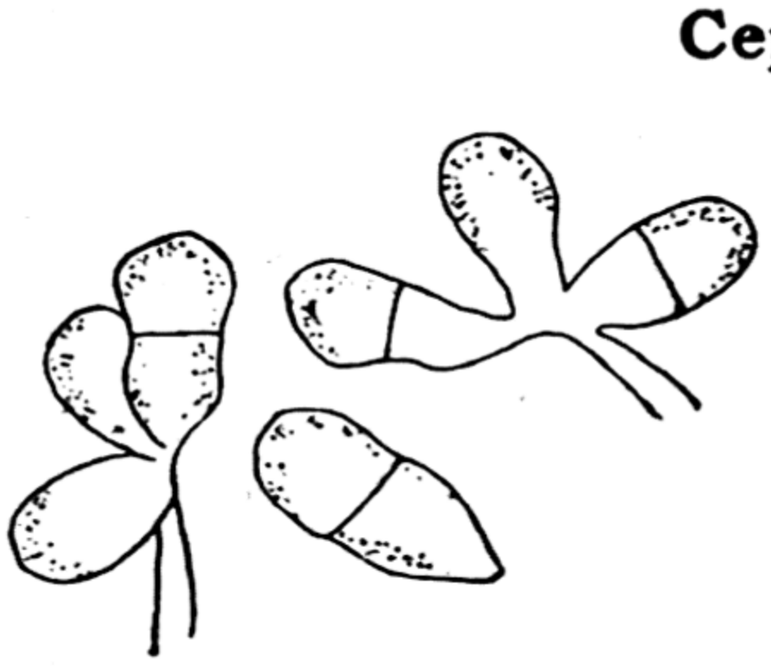


FIG. 392.—Spores of Cephalothecium roseum. After Eustace.

Hyphæ prostrate; conidiophores erect, simple, septate, conidia apical, subcapitate, oblong to pyriform, hyaline.

Five species, chiefly saprophytes.

C. roseum Cda.[260–263]

Cespitose in subrotund, rose colored spots, fading with age, byssoid; hyphæ creeping, branched; conidiophores erect, simple, continuous, hyaline; conidia oblong-ovate, constricted at the septum, capitate, light rose.

It is often found following apple scab gaining entrance through

the injured cuticle and causing rot. A ring of pink conidiophores and conidia is formed around the margin of the scab. Inoculation tests showed the fungus unable to penetrate through sound cuticle though it readily made entrance through wounds. It has been occasionally reported on living twigs and leaves and as a common saprophyte has long been known. The first account of it in America was from New York [260] in 1902 though it was described in 1899 as injuring pears in Germany.[262]

Mycogone Link (p. 586)

Hyphæ intricately branched; conidiophores short, lateral; conidia unequally 2-celled, the upper larger, echinulate.

There are about fifteen species of mycogenous fungi which are probably conidial stages of Hypomyces. See p. 200.

M. perniciosa Mag.[264, 265]

White throughout, byssoid, deforming the host; conidiophores short; conidia solitary, more or less pyriform, almost colorless, 17–22 x 9–12 μ.

It is reported by Mrs. Patterson as the cause of a mushroom disease in America. A verticillium conidial stage was present but no ascigerous form.

M. rosea Link. also occurs on mushrooms.

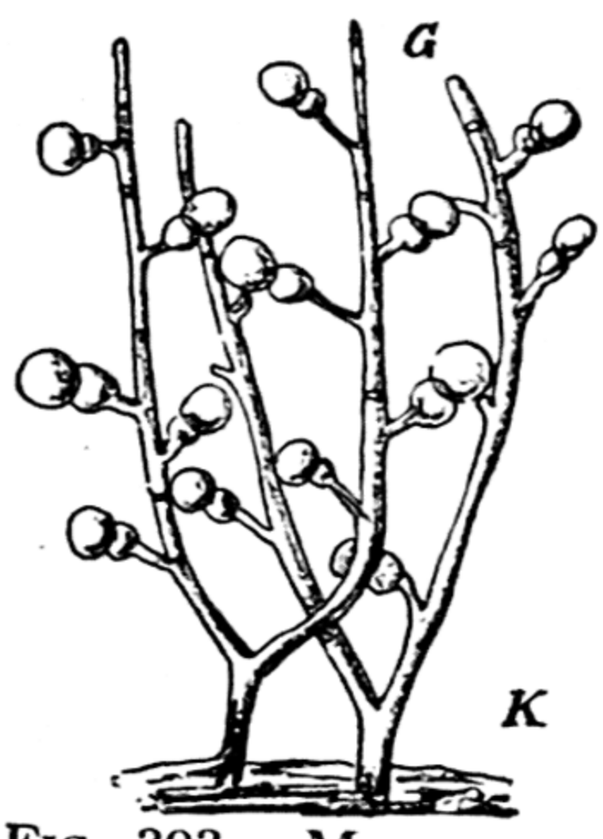


FIG. 393.—Mycogone, conidiophores and conidia. After Saccardo.

Rhynchosporium Heinsen (p. 586)

On leaf spots; hyphæ filiform, hyaline, creeping, septate; conidiophores erect, with incurved branches, hyaline, apically denticulate; conidia short-cylindric, with a short oblique beak, medially septate, hyaline. A monotypic genus.

R. graminicola Hein. occurs on rye, wheat, and barley in Europe.

Didymaria Corda (p. 586)

Conidiophores simple, conidia borne apically, ovate, hyaline. About twenty species of leaf parasites.

D. prunicola Cav. produces spots on plum leaves.

Moniliaceæ-Phragmosporæ (p. 565)

Conidia hyaline or bright colored, 2 to several-septate, oblong, fusoid or elongate.

Key to Genera of Moniliaceæ-Phragmosporæ

Fertile hyphæ very short and little different from the conidia
- Conidia in chains, cylindric or oblong.. — 1. **Septocylindrium,** p. 589.
- Conidia not in chains
  - Sporophore 3-celled, upper cell much inflated. — 2. **Milowia.**
  - Sporophore not inflated, sometimes obsolete
    - Conidia ciliate at apex and upper septum. — 3. **Mastigosporium,** p. 590.
    - Conidia not ciliate
      - Hyphæ lacking; conidia not aggregate. — 4. **Fusoma,** p. 590.
      - Hyphæ distinct; conidia aggregate
        - Conidia in mucose glomerules. — 5. **Rotaea.**
        - Conidia in fascicles, not mucose. — 6. **Paraspora.**

Fertile hyphæ manifest and distinct from the conidia
- Saprophytic
  - Conidia solitary or at least not capitate
    - Fertile hyphæ simple
      - Sterile hyphæ lacking. — 7. **Dactylella.**
      - Sterile hyphæ abundant. — 8. **Monacrosporium.**
    - Fertile hyphæ branched
      - Hyphæ verticillately branched.. — 9. **Dactylium.**
      - Hyphæ irregularly branched. — 10. **Blastotrichum.**
- Conidia capitate
  - Fertile hyphæ vesiculose at tip — 11. **Cephaliophora.**
  - Fertile hyphæ not swollen
    - Hyphæ simple, sterile lacking — 12. **Dactylaria.**

Hyphæ verticillate; sterile hyphæ present.	13. **Mucrosporium.**
Parasitic	
Conidia mucose-conglobate, allantoid, often continuous.	14. **Allantospora.**
Conidia not mucose-conglobate	
Conidia ovate-cylindric or elongate, often catenulate.	15. **Ramularia,** p. 590.
Conidia obclavate-pyriform.	16. **Piricularia,** p. 591.

Septocylindrium Bonardin (p. 588)

Conidiophores very short, scarcely distinct from the conidia, or in parasitic species distinct but short and inflated or denticulately sublobate at the apex; conidia oblong or cylindrical, one to many-septate, catenulate, the chains often branched.

About thirty species, a few of them of economic importance.

S. areola (Atk.) P. & C.[266, 267]

Spots amphigenous, pale, becoming darker in age, 1 to 10 mm., angular, limited by the veins of the leaf, conidiophores amphigenous, fasciculate, subnodose, branched or not, several times septate, hyaline, 25–75 x 4–7 μ; conidia oblong, usually abruptly pointed at the ends, catenulate or not, 14–30 x 4–5 μ, hyaline.

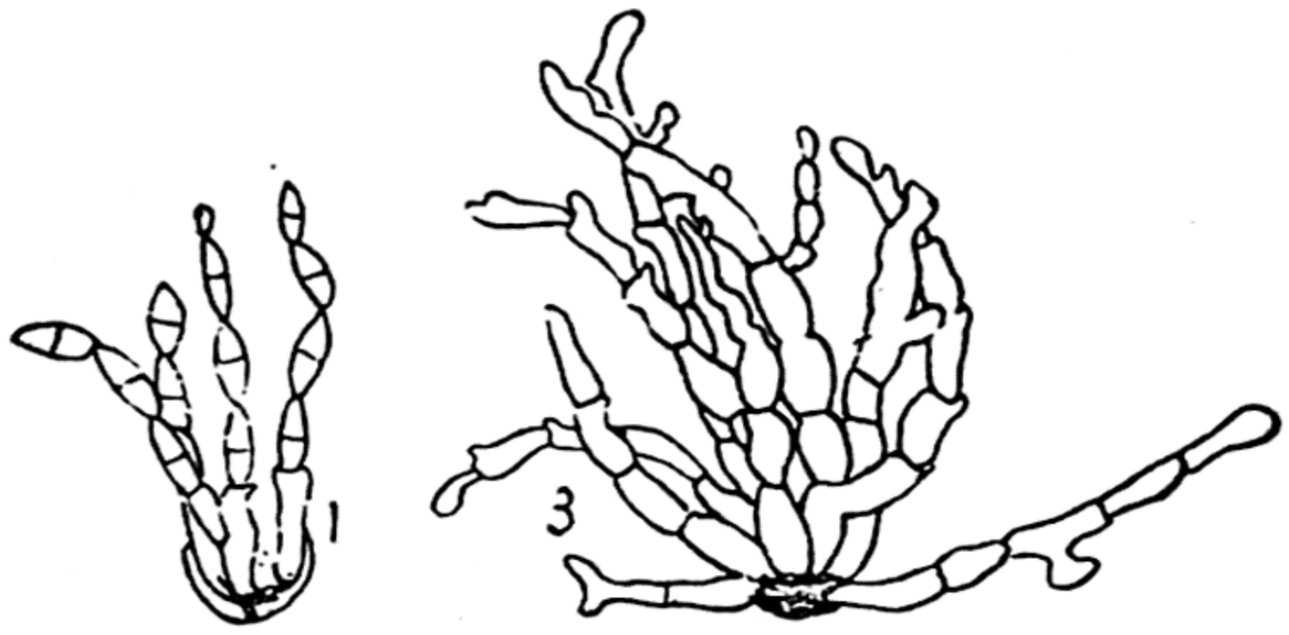


FIG. 394.—S. areola. After Atkinson.

Leaf spots are produced on cotton. The conidia and stalks are so abundant on the undersides of spots as to give them a frosted appearance.

S. rufomaculans (Pk.) P. & C.

Spots numerous or confluent and even covering the entire leaf, reddish; conidiophores very short, hypophyllous, cespitose; conidia catenulate, variable, ellipsoid-oblong to cylindric, hyaline, 8–16 x 3–4 μ.

It is somewhat injurious on buckwheat in America.[268]

S. radicicolum Aderh [249] is reported by Aderhold as the cause of death of roots of Prunus and Pyrus.

Mastigosporium Riess (p. 588)

Conidiophores short, stipitate, continuous, hyaline, conidia fusoid, large, 3-septate, hyaline, with apical and subapical bristles. A small genus in part = Dilophia.

Fusoma Corda (p. 588)

Mycelium obsolete or poorly developed; conidia innate, fusiform separate.

F. parasiticum Percival, causes a wilt of hops.[457]

Ramularia Unger (p. 589)

Conidiophores fasciculate, simple or with short, scattered branchlets, often flexuose, nodulose, or denticulate towards the apex, hyaline or light colored; conidia acrogenous or acropleurogynous on the denticulations, hyaline, sometimes subcatenulate, oblong, cylindric, typically many-septate.

About three hundred species. In part = Mycosphærella. See p. 243.

R. tulasnei Sacc. on strawberry = Mycosphærella fragariæ. See p. 244.

R. armoraciæ Fcl.[19]

Spots amphigenous, subochraceous becoming gray; conidiophores fasciculate, continuous, subsimple, 40–50 x 2.5–3 μ; conidia rod-shaped, obtuse, hyaline, 15–20 x 3–4 μ.

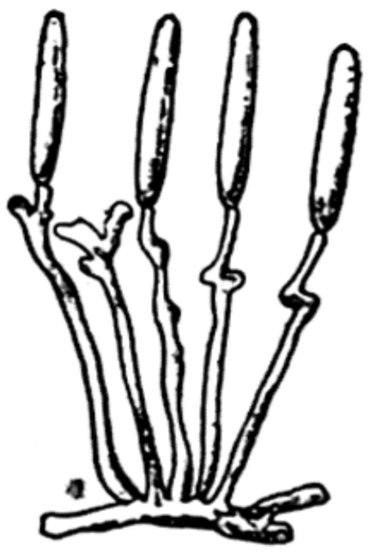


FIG. 395.—R. armoraciæ. After Saccardo.

On horseradish causing leaf spots.

R. taraxaci Karst.

Hypophyllous, spots purple-margined, hyphæ 35–45 x 2–3 μ, spores bacillar, simple, straight, hyaline, 18–30 x 2–3 μ.

On dandelion.

R. spinaciæ Nip. is on spinach;

R. betæ Rost. on beet;

R. necator Mas. on cacao;

R. geranii (West.) Fcl. on cultivated geraniums

R. primulæ Thüm.

Spots rounded-angular, subochraceous, emarginate; conidiophores amphigenous, 50–60 x 5 μ, continuous, somewhat denticulate, rarely branched; conidia fusoid-cylindric, 20–30 x 3–6 μ, continuous or 1-septate. On Primula.[26]

R. lactea (Desm.) Sacc. is on violets;

R. heraclei (Oud.) Sacc. on cultivated Heracleums;

R. onobrychidis P. & D. on leaves of sainfoin.

R. cynaræ Sacc. causes loss of artichokes in France and Africa.

R. coleosporii Sacc. is on sweet potato in Porto Rico.[269]

R. modesta Sacc. is recorded for the strawberry.

R. narcissi Chit. and **R. vallambrosæ** Br. & Cav. cause disease of leaves and stalks of Narcissus.[270]

R. gœldiana Sacc. kills twigs of coffee.

Piricularia Sacc. (p. 589)

Conidiophores simple, rarely branched, conidia obclavate to pyriform, 2 to many-septate, solitary acrogenous, hyaline.

A small genus of parasites.

P. grisea (Cke.) Sacc.[271-273] produces pallid or water-soaked, spots on culms and leaves, with age greyish; conidiophores in clusters of two or five from the stomata, simple or rarely sparingly branched, greyish, septate; conidia single, terminal in scorpioid cymes, ovate, 2-septate, 24–29 x 10–12 μ.

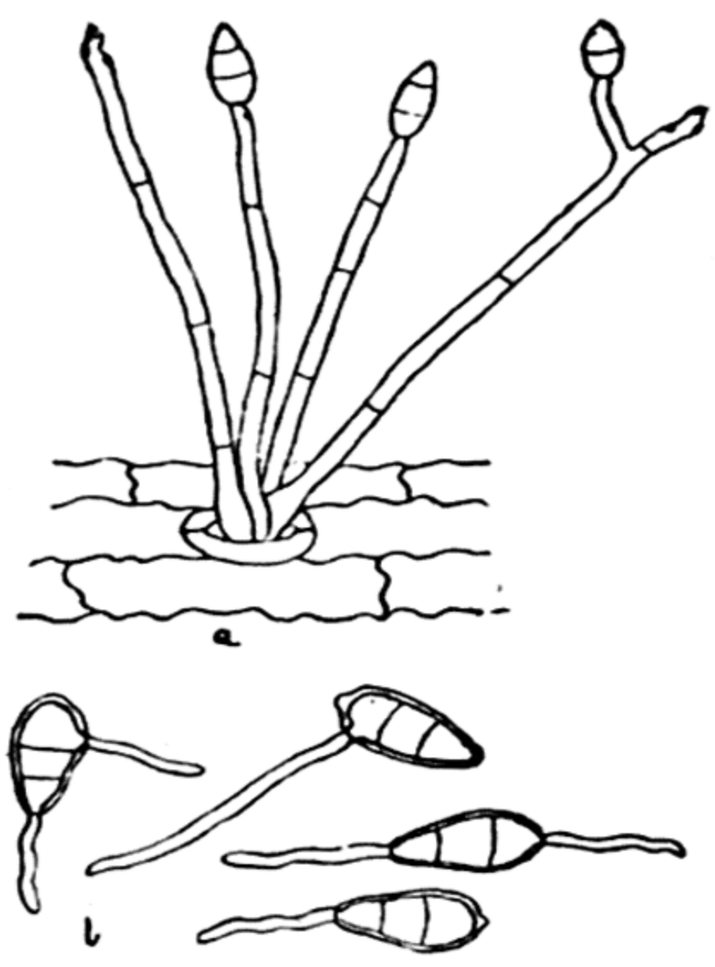


FIG. 396.—Piricularia grisea. *a*, conidiophores. *b*, germinating spores. After Fulton.

It causes death of rice plant tissue and the disease called "blast." If affected leaves or stalks be placed in a damp atmosphere for about a day a delicate greyish fungus, the sporing mycelium appears. The fungus grows well in culture and applied to the rice plants gives rise to the typical disease spots. This species was originally described on Digitaria sanguinalis and the form on rice has been called

P. oryzæ; but morphological characters and inoculation experiments indicate their identity on various other grasses.

P. caudata A. & S. occurs on cacao.

To the **Moniliaceæ-scolecosporæ** belongs only one genus:

Cercosporella Saccardo

Hyaline throughout; conidiophores simple or branched; conidia filiform, many-septate. Distinguished from Cercospora only in color. The genus contains some seventy species of parasites.

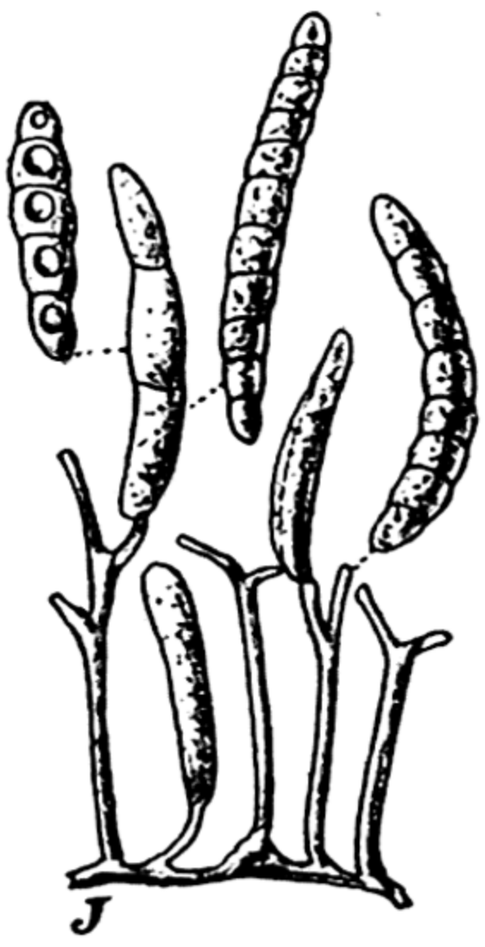


FIG. 397.—C. persicæ. After Saccardo.

C. persicæ Sacc.[274]

Conidiophores cespitose, on discolored areas, filiform, 2 to 3-branched, continuous; conidia 40–60 x 1–5 μ, torulose.

The conidia develop in abundance on the lower sides of leaf spots of peach causing a frosty mildew.

C. narcissi Boud. occurs on Narcissus;

C. inconspicuus (Wint. & Hohn) on lily.

C. pastinacæ Karst.

Spots amphigenous, fuscus or whitish; conidia filiform, somewhat curved, slender, attenuate, 50–90 x 2 μ.

On parsnip and other Umbelliferæ.

C. albo-maculans E. & E.

Spots orbicular, white, dark-margined, conidiophores amphigenous, cespitose, 8–12 x 2 μ, hyaline, continuous; conidia cylindric, 40–68 x 2–2.5 μ, straight or curved, 3-septate.

A common cause of pale spots on turnip leaves.

Moniliaceæ-Dictyosporeæ (p. 565)

Conidia hyaline or bright colored, muriform, globose, ovoid or cubic.

KEY TO GENERA OF **Moniliaceæ-Dictyosporeæ**

Saprophytic

Hyphæ much-branched; conidia elliptic or globose, cells uniform..... 1. **Stemphyliopsis.**

Hyphæ little-branched; conidia six-lobed and sarcinæform, central cell larger, colored, lobes hyaline. . . . . 2. **Synthetospora.**
Parasitic. . . . . 3. **Hyalodema,** p. 593.

This group contains but one important pathogen, **Hyalodema evansii** Mag., recently described by Magnus [275] on Zizyphus in Africa.

The **Moniliaceæ-Helicosporæ** contain no important parasites.

Moniliaceæ-Staurosporæ (p. 565)

Conidia hyaline or bright colored, stellate, radiate or forked, septate or continuous.

Key to Genera of Moniliaceæ-Staurosporæ

Hyphæ lacking; conidia trident-shaped. . . . 1. **Tridentaria.**
Hyphæ present
  Conidia globose to cylindric, permanently attached to 2 or 3 divergent sterigmata. . . . . 2. **Tetracladium.**
  Conidia themselves stellate or radiate
    Conidia bilobate-forked; lobes parallel, contiguous. . . . . 3. **Pedilospora.**
    Conidia narrowly digitate. . . . . 4. **Prismaria.**
    Conidia 3 to 4-radiate
      Conidia ciliate at the apex. . . . . 5. **Titæa,** p. 593.
      Conidia muticate
        Conidia 3-radiate. . . . . 6. **Trinacrium.**
        Conidia 4-radiate
          Fertile hyphæ very short, simple 7. **Tetracium.**
          Fertile hyphæ branched. . . . . 8. **Lemonniera.**

Titeæ Saccardo

Conidiophores simple, continuous; conidia subradiately 4 to 5-celled, the cells unequal in size.

A small genus of little economic importance.

T. maxilliformis Rost. has been found on the roots of clover in Denmark.[276]

Dematiaceæ (p. 565)

Hyphæ dark or black, cobwebby, loose, usually rigid, not cohering in definite fascicles; conidia typically dark and concolorous, but sometimes the hyphæ are dark and conidia clear, or the conidia dark and the hyphæ clear. This family parallels the Moniliaceæ and certain intermediate forms must be sought in both.

Key to Sections of Dematiaceæ

Conidia globose, ovate, oblong or short cylindric
- Conidia continuous. . . . . 1. **Amerosporæ**, p. 594.
- Conidia 2-celled. . . . . 2. **Didymosporæ**, p. 601.
- Conidia 3 or more-celled. . . . . 3. **Phragmosporæ**, p. 608.
- Conidia muriform. . . . . 4. **Dictyosporæ**, p. 615.

Conidia long, filiform or vermicular . . . . . 5. **Scolecosporæ**, p. 625.

Conidia cylindric, spiral or convolute, typically septate. . . . . 6. **Helicosporæ.**

Conidia of several stellately grouped cells. . . 7. **Staurosporæ.**

Dematiaceæ-Amerosporæ

Conidia continuous, globose to oblong.

Key to Subfamilies of Dematiaceæ-Amerosporæ.

Conidiophores very short, scarcely distinguishable from the mycelium
- Conidia borne singly. . . . . 1. **Coniosporieæ**, p. 595.
- Conidia catenulate. . . . . 2. **Toruleæ**, p. 595.
- Conidia in heads or racemes. . . . . 3. **Echinobotryeæ.**

Conidiophores manifest and distinct from the mycelium and spores
- Conidia dark, rarely subhyaline
  - Conidia not in chains
    - Conidia capitate. . . . . 4. **Periconieæ**, p. 597.
    - Conidia verticillate, or at least lateral. . . . . 5. **Anthrinieæ.**
    - Conidia borne singly on short lateral branches. . . . . 6. **Trichosporieæ**, p. 598.

Conidia solitary, acrogenous.	7. **Monotosporeæ**, p. 600.
Conidia in chains.	8. **Haplographieæ**, p. 600.

Conidia hyaline

Conidia acrogenous on short heteromorphic conidiophores at the lower part or bases of erect hyphæ

Conidia single or catenulate.	9. **Sarcapodieæ.**
Conidia in heads.	10. **Myxotrichelleæ.**

Conidia on hyphæ of the same kind

Conidia in heads.	11. **Stachylidieæ.**
Conidia in chains.	12. **Chalarieæ.**

Conidiosporieæ (p. 594)

Conidia not catenulate, conidiophores short.

Key to Genera of Coniosporieæ

Conidia spherical, elliptic or discoid.	1. **Coniosporium**, p. 595.
Conidia elongate.	2. **Fusella.**

Coniosporium Link

Hyphæ very much reduced; conidia dark, globose, ovoid or discoid, borne on short hyaline conidiophores.

About eighty-five species, chiefly saprophytes.

C. onobrychidis Mag. occurs on sainfoin;

C. filicinum Rost. on Pteris and other ferns.



Fig. 398. — Coniosporium. After Saccardo.

Toruleæ (p. 594)

Conidia in chains.

Key to Genera of Toruleæ

Conidia of two sorts, macroconidia catenulate

Microconidia glomerate.	1. **Heterobotrys.**
Microconidia internal, catenulate.	2. **Thielaviopsis**, p. 596.

Conidia all alike

Hyphæ dark

Chains breaking up readily

Conidia globose or ovoid.	3. **Torula**, p. 597.

Conidia clavate.....	4. **Gongromeriza.**
Chains breaking up with difficulty	
Chains curved.....	5. **Gyroceras.**
Chains straight or nearly so.....	6. **Hormiscium.**
Hyphæ hyaline.....	7. **Monilochætes,** p. 597.

Thielaviopsis Went.[23] (p. 595)

Hyphæ creeping, subhyaline; conidiophores simple, septate; conidia of two kinds; macroconidia catenulate, ovate, fuscous;

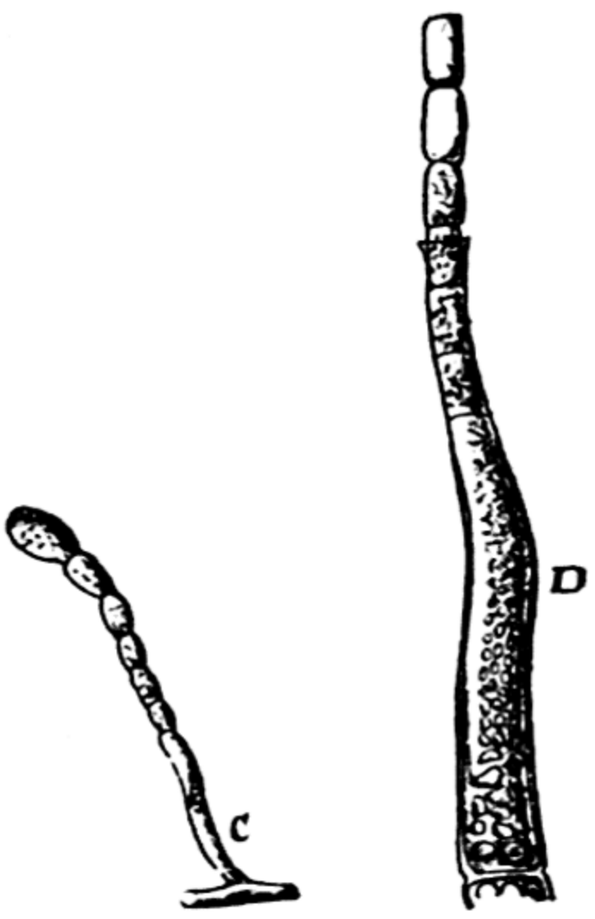


FIG. 399.—T. ethaceticus. After Wakker and Went.

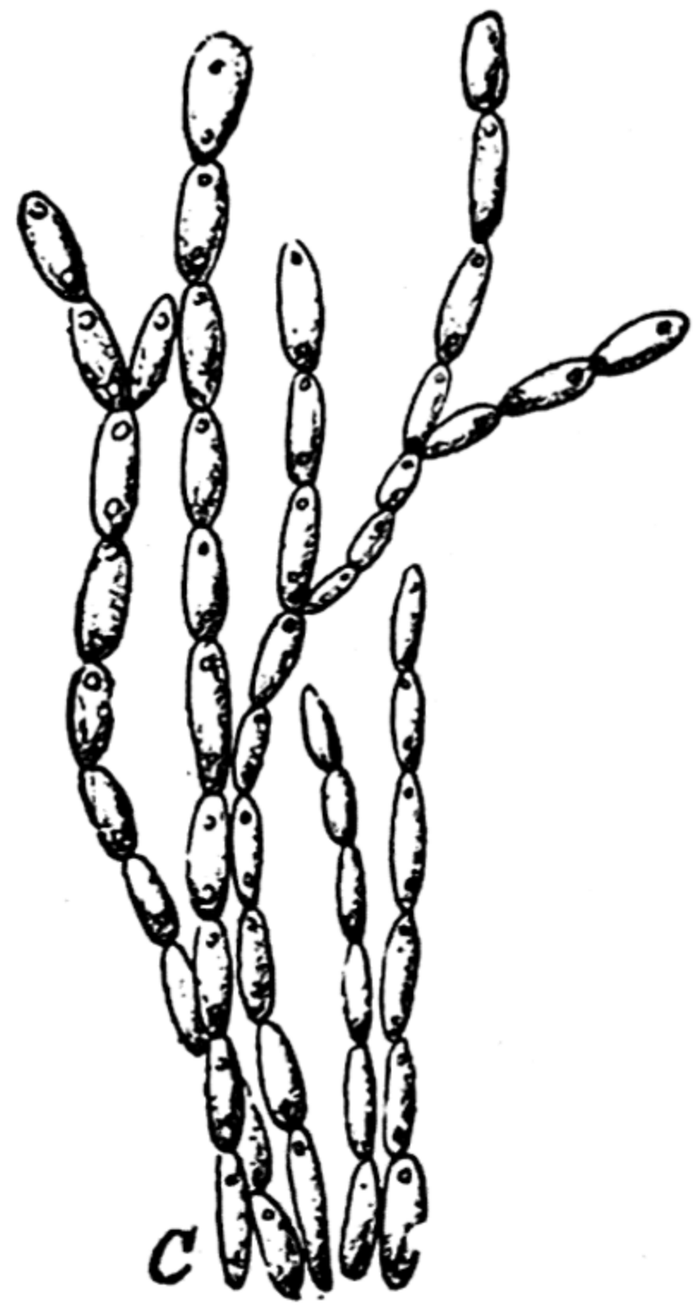


FIG. 400.—Torula. After Saccardo.

microconidia cylindric, hyaline, catenulate within the conidiophore. In part=Trichosphæria.

Only two species, both of economic importance.

T. paradoxa (d. Seyn) v. Höhn (=Chalara paradoxa.)

Macroconidia 16–19 x 10–12 μ; microconidia 10–15 x 3.5–5 μ.

It is the cause of a pineapple rot, in which rôle it was first described in 1886; and of a sugar cane disease.[277]

In addition to micro and macrospores the fungus possesses a pycnidial form. With variation of the substratum the spores vary

considerably from the typical. In disinfection tests Patterson and Charles [23] showed the macrospores to be considerably more resistant than the microspores, also that fumigation kills superficial spores and spores placed in incisions in the fruit.

T. podocarpi Pet. is known from Podocarpus roots.[278]

Torula Persoon (p. 595)

Hyphæ decumbent; conidiophores short, scarcely different from the conidia, which are catenulate, breaking away singly or in groups, dark to black, oblong to fusoid, smooth or roughened.

Some one hundred fifty species, chiefly saprophytes.

T. exitiosa d. Seyn is said to cause much injury to chestnuts.

T. sphærella Cke. causes a sooty mold of coffee.

Monilochætes Ellis & Halsted [330] (p. 596)

Hyphæ brown; conidiophores obsolete or very short, conidia like; conidia in chains, moniliform, dark; some chains interspersed with larger conidia.

Monotypic and poorly known.

M. infuscans Ell. & Hals.[330]

The mycelium grows subepidermally in sweet potato roots causing discoloration and withering. The conidiophores arise from the surface bearing their simple chains of conidia.

Periconieæ (p. 594)

Conidia dark, capitate.

Key to Genera of **Periconieæ**

Fertile hyphæ simple, but often with short apical branches	
Hyphæ with apical branches or conidiophores	
Parasitic	**1. Periconiella.**
Saprophytic	
Apex with heterogeneous conidiophores	
Apex swollen; conidiophores 3 to 4	**2. Haplobasidium.**

Apex not swollen; conidiophores many..... 3. **Stachybotrys.**
Apex short-branched, rarely simple
Apex short-branched or simple
Apex not swollen. ..... 4. **Periconia,** p. 598.
Apex swollen. ..... 5. **Stachybotryella.**
Apex capitate-branched; branches 2 to 3-furcate and spine-bearing..... 6. **Cephalotrichum.**
Hyphæ without apical branches or conidiophores
Conidia globose. ..... 7. **Trichobotrys.**
Conidia boat-shaped curved; hyphæ dark-ringed. ..... 8. **Camptoum.**
Conidia fusoid, sometimes subhyaline. ..... 9. **Acrotheca.**
Fertile hyphæ branched below the apex
Hyphæ forked below apex; conidia oblong..... 10. **Synsporium.**
Hyphæ repeatedly dichotomous; conidia globose or elliptic. ..... 11. **Dicyma.**

Periconia Bonordin [279]

Hyphæ creeping, or obsolete; conidiophores simple, dark, apically fertile; conidia globose, fuscous, solitary on short sterigmata. Fig. 401.

Some forty species chiefly saprophytes.

Trichosporieæ (p. 594)

Conidia dark, borne singly on short lateral branches.

Key to Genera of **Trichosporieæ**

Hyphæ loose, typically saprophytic
Hyphæ vesiculose-inflated here and there
Conidia-bearing vesicles pleurogynous. 1. **Œdemium.**
Conidia-bearing vesicles acrogenous... 2. **Cystophora.**
Hyphæ not vesiculose-inflated
Fertile hyphæ erect

Branches circinate at apex; conidia mesogenous, muricate. . . . . 3. **Acrospeira.**
Branches spirally twisted; conidia exogenous. . . . . 4. **Streptothrix,** p. 599.
Hyphæ simple or with straight branches. . . . . 5. **Virgaria.**
All hyphæ more or less creeping
Branches curved or lash-like. . . 6. **Campsotrichum.**
Branches not curved
Conidia spiny, rarely smooth. . . . . 7. **Zygodesmus,** p. 599.
Conidia smooth
Conidia sessile. . . . . 8. **Trichosporium.**
Conidia on stalks
Conidia on tooth-like sterigmata. . . . . 9. **Rhinocladium.**
Conidia on jar-like stalks . . . . 10. **Basisporium.**
Hyphæ forming a crust, parasitic . . . . . 11. **Glenospora.**

Streptothrix Corda

Conidiophores erect, monopodially branched, the branches spirally coiled; conidia apical or lateral, single, sessile or with short sterigmata, dark colored.

A small genus. **S. dassonvillei** Broc-Ros. is noted as the cause of mold of grain and fodder.[337]

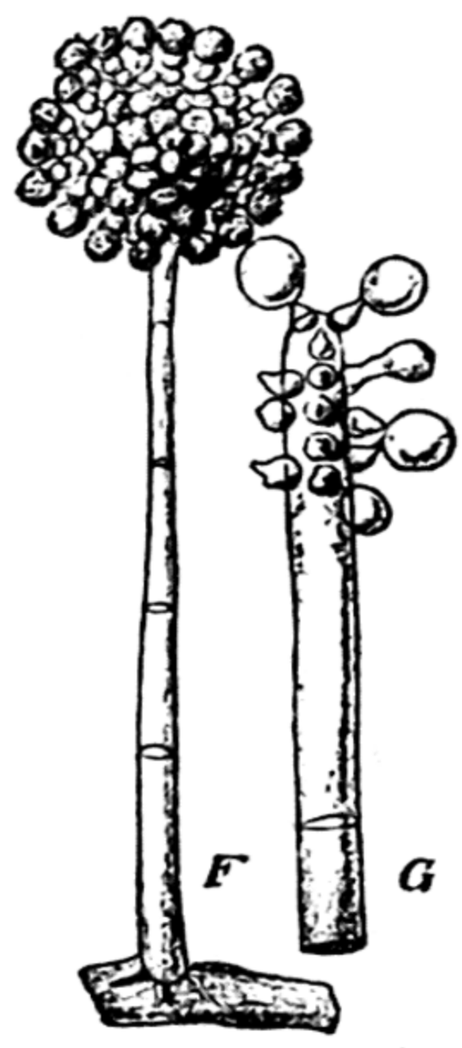


FIG. 401.—Periconia. After Saccardo.

Zygodesmus Corda

Hyphæ and conidiophores creeping, the latter branched, light or dark colored, here and there irregularly inflated, septate at the swellings; conidia globose or ovate, muricate, rarely smooth, on short sterigmata or on basidia-like branches of the sterigmata.

Some fifty species, chiefly non-parasitic.

Z. albidus E. & H.[18]

Halsted describes a disease characterized by a floury coating on violet leaves and ascribes it to this species.

Monotosporeæ (p. 595)

Conidia dark, solitary, acrogenous.

Key to Genera of Monotosporeæ

Sterile hyphæ lacking	
Fertile hyphæ short and fascicled at base.	1. **Hadrotrichum.**
Fertile hyphæ longer, separate.	2. **Monotospora.**
Sterile hyphæ present	
Conidia with a loose hyaline membrane.	3. **Nigrospora.**
Conidia without a membrane	
Conidia with a large shining drop. . .	4. **Sporoglena.**
Conidia without a shining drop.	5. **Acremoniella, p. 600.**

Acremoniella Saccardo

Hyphæ creeping, simple or ramose, hyaline or colored; conidiophores simple, short, subbulbous below; conidia globose to ovoid, fuscous.

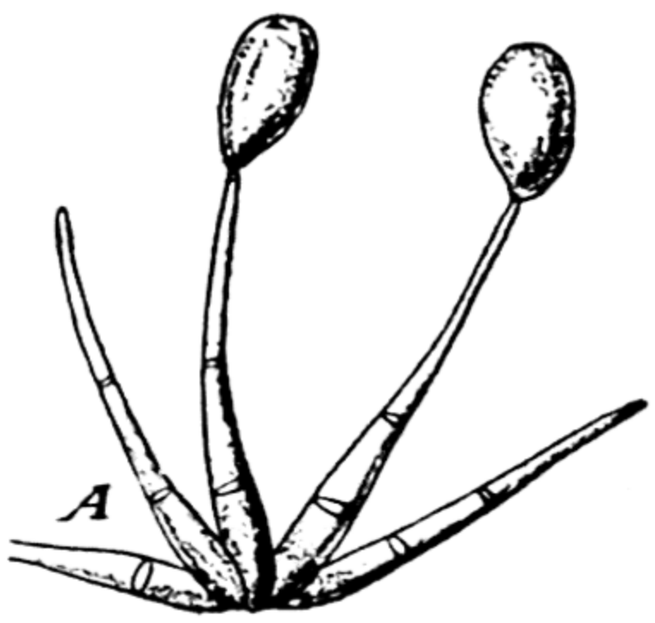


Fig. 402.—Acremoniella. After Bonorden.

About a dozen species.

A. occulta Cav.[280] forms brownish-yellow flakes on the stems of cereals;

A. verrucosa Togn. on wheat in Italy.

Haplographieæ (p. 595)

Conidia dark, catenulate.

Key to Genera of Haplographieæ.

Sterile hyphæ all creeping or obsolete	
Fertile hyphæ simple, not branched at tip	
Chains of conidia lateral.	1. **Dematium.**
Chains terminal	
Conidia without isthmi	2. **Catenularia.**
Conidia connected by cylindric isthmi.	3. **Prophytroma.**
Fertile hyphæ branched	
Hyphæ dendroid.	4. **Hormodendrum, p. 601.**

Hyphæ capitate branched at tip.... 5. **Haplographium.**
Some sterile hyphæ erect and mixed with the fertile..... 6. **Hormiactella.**

Hormodendrum Bonarden (p. 600)

Hyphæ creeping; conidiophores erect, septate, brown, variously dendritically branched; conidia catenulate on the branches, globose, ovoid, olivaceous to fuscous.

About a dozen species.

H. hordei Bruhne on barley stems and leaves often reduces the yield.

Spots brown, scattered over the entire leaf or confluent, oblong; hyphæ simple, septate; conidia various, cylindric, rounded or subattenuate, or ellipsoid to subglobose, verrucose.



FIG. 403.—H. hordei. After Bruhne.

Dematiaceæ-Didymosporæ (p. 594)

Conidial 1-celled, dark, rarely hyaline, ovoid or oblong.

KEY TO GENERA OF **Dematiaceæ-Didymosporæ**

Hyphæ very short or scarcely different from the conidia
  Conidia not in chains
    Hyphæ lacking..... 1. **Dicoccum,** p. 602.
    Hyphæ present, circinate..... 2. **Cycloconium,** p. 602.
  Conidia in chains..... 3. **Bispora.**
Hyphæ distinctly different from the conidia
  Conidia smooth, muticate
    Conidia not capitate
      Conidia more or less catenulate at first
Hyphæ and conidia biform, the latter 1-celled or continuous, dark or hyaline..... 4. **Epochnium.**
Hyphæ and conidia uniform
  Hyphæ here and there inflated 5. **Cladotrichum.**

Hyphæ not inflated
Hyphæ erect; conidia long-catenulate. . . . . 6. **Diplococcium,** p. 603.
Hyphæ somewhat decumbent; conidia short-catenulate or finally solitary. . . . . 7. **Cladosporium,** p. 606.
Conidia not catenulate
Hyphæ beautifully flexuose-torulose. . . . . 8. **Polythrincium,** p. 603.
Hyphæ not torulose or flexuose
Hyphæ inflated at tip, branched 9. **Pseudobeltrania.**
Hyphæ not inflated, usually short and little branched
Conidia merely acrogenous
Conidiophores short, 1 or 2-septate. . . . . 10. **Fusicladium,** p. 606.
Conidiophores rather long, multiseptate. . . . . 11. **Passalora,** p. 607.
Conidia acro-pleurogenous. . . 12. **Scolecotrichum,** p. 607.
Conidia capitate. . . . . 13. **Cordana.**
Conidia muriculate or ciliate
Conidia muriculate. . . . . 14. **Trichocladium.**
Conidia ciliate at apex; fertile and sterile hyphæ intermixed. . . . . 15. **Beltrania.**

Dicoccum Corda (p. 601)

Hyphæ creeping, chiefly very short, simple; conidia elongate or short-clavate, dark.

About a dozen species.

D. rosæ Bon. produces spots on rose leaves.

Cycloconium Castaigne (p. 601)

Hyphæ in the walls of the epidermis, dichotomous branched, very fugacious, black; conidia ovoid, solitary.

There is one species:

C. oleaginum Cast. Mycelium circinate, fugacious, black; conidia sessile, ovoid, yellow-green.

It forms blotches on olive leaves and on peduncles of the fruit in Italy and France and is somewhat injurious in California.[284]

Diplococcium Grove (p. 602)

Conidiophores erect, septate, branched, olivaceous; conidia catenulate, 2-celled.

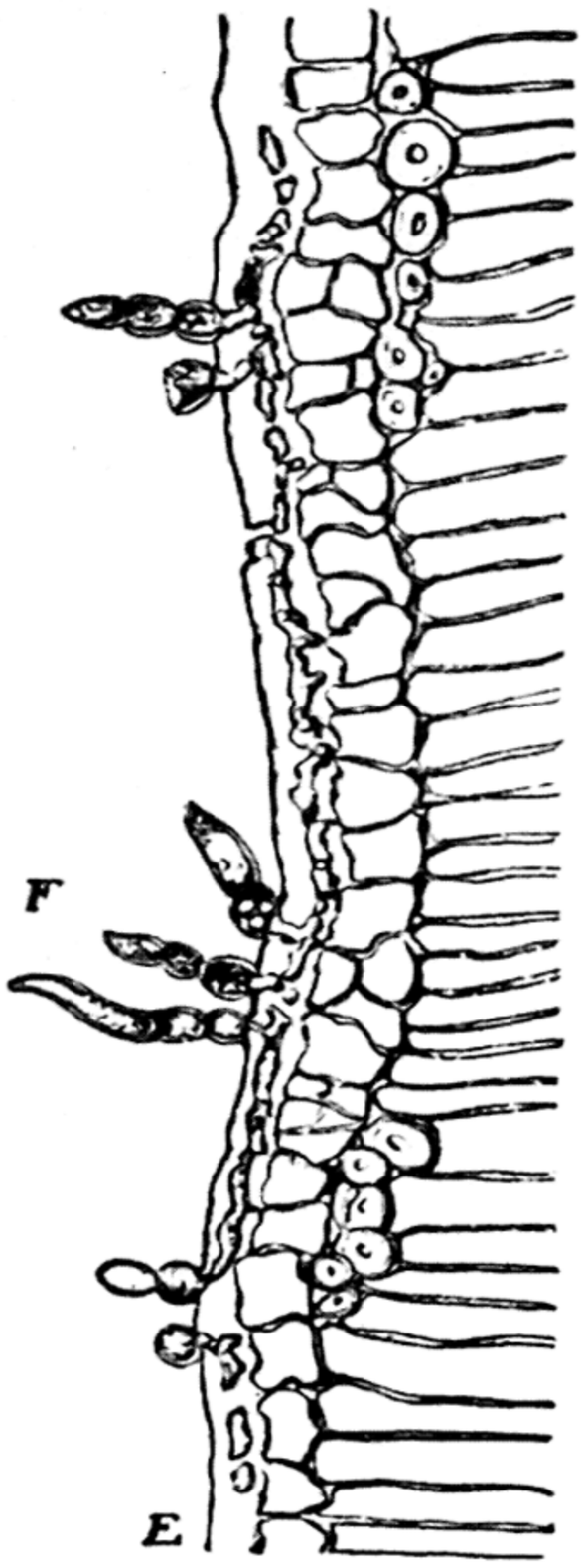


FIG. 404. — Cycloconium oleaginum. After Boyer.

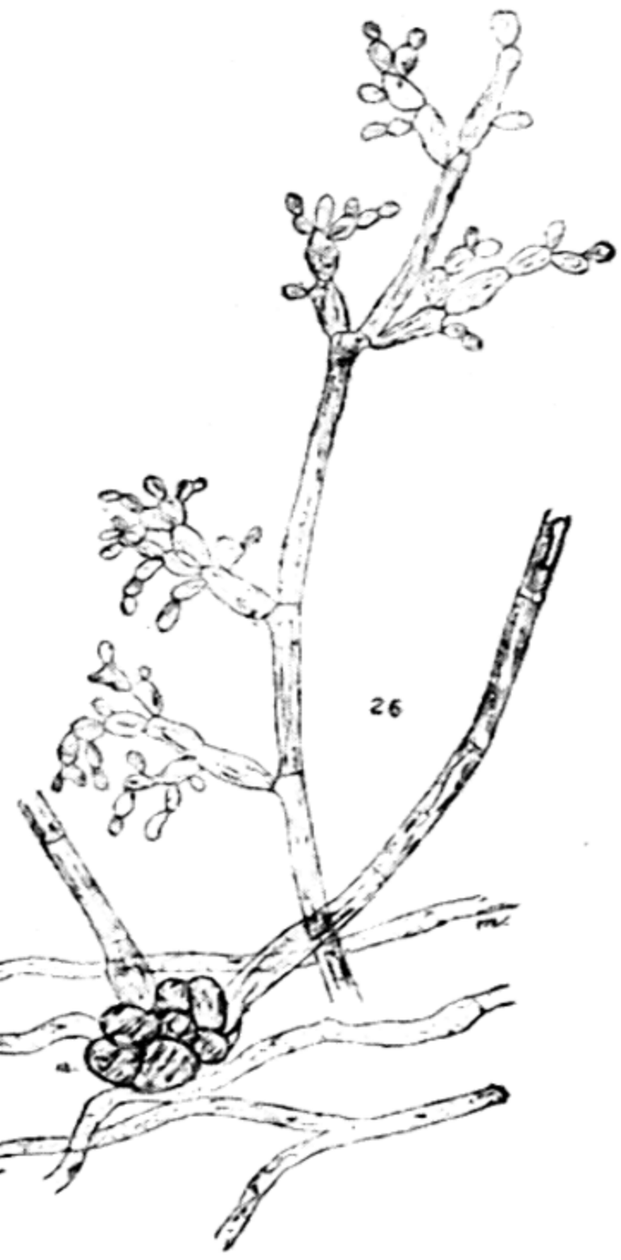


FIG. 405. – Clodosporium cucumerinum, mycelium, a hyphal knot, conidiophore and spores. After Humphrey.

D. conjunctum (Bon) Sacc. is reported as a parasite of the geranium.[458]

Cladosporium Link (p. 602)

Hyphæ decumbent, intricately-branched, olivaceous; conidia globose to ovoid, greenish. In part=Mycosphærella. See p. 243.

Some one hundred seventy-five species, many of them of economic importance.

C. fasciculare Fr. on hyacinth=Pleospora hyacinthi. See p. 260.

C. herbarum (Pers.) Lk. on many hosts=Mycosphærella tulasnei. See p. 247.

C. herbarum (Pers.) Lk. var. **citricolum.**[281, 282]

Fawcett [340] recognizes this as the cause of scaly bark of Citrus. The fungus was grown in pure culture and inoculations were made resulting in from forty to sixty days in typical spots. From these the fungus was re-isolated.

C. cucumerinum E. & A.[27, 285-287]

Effused, maculose; in mass greyish-brown, changing to dark olivaceous, forming spots on fruits; condiophores cespitose, sparingly septate, simple, denticulate, pale; conidia ovoid, lemon-shaped or fusoid; olivaceous, 10–13 x 3–4 μ. It causes watery spots on cucumber leaves, also decayed spots in fruit.

C. elegans Penz. is the cause of disease on various kinds of oranges in Italy. This species is in the literature much confused with the next.

C. citri Mas.[283, 288-291]

Conidiophores tufted, erect, branched, septate, brown, 30–75 x 2–4 μ; conidia fusiform, dusky, continuous, or 1 to 3-septate, 8–9 x 2.5–4 μ.

The cause of scab on lemons, sour oranges, satsumas and pomelos. It was grown in artificial culture by Fawcett.

C. carpophilum Thüm.[26, 292-294, 459]

Spots orbicular, often confluent, blackish-green, forming circles; conidiophores erect, simple, sinuous, septate; conidia ovate, obtuse, continuous or 1-septate, 10–12 x 4–6 μ.



FIG. 406. — C. carpophilum. After Cobb.

This is the cause of the widely distributed scab of peach, plum, nectarine, apricot, cherry. The deep olive-brown hyphæ are found intermingled with the hairs of the peach. The disease was first noted in Austria in 1877. The fungus was cultured and inoculations were made by Chester.[292]

In the twig the fungus breaks the cuticle from the layers below and its hyphæ project through cracks. Upon the leaf it causes shot holes.

C. sicophilum Far. attacks fig fruits.

C. fulvum Cke.[32]

Conidiophores densely crowded rupturing the cuticle, sparingly branched, septate, nodulose, bearing a few conidia near the apex;

conidia elliptic-oblong, 1-septate, translucent, tawny, 10–20 x 4–6 μ.

The hyphæ are abundant on the lower sides of tomato leaves, forming a mold, varying from whitish to purplish in color.

It causes serious disease in Europe and America.

C. condylonema Pass. is found on leaves of Prunus causing leaf spot and curl.

C. bigarardia is on Citrus.

C. macrocarpum Preu.[20]

Subeffuse, black; conidiophores subfasciculate, simple, some-

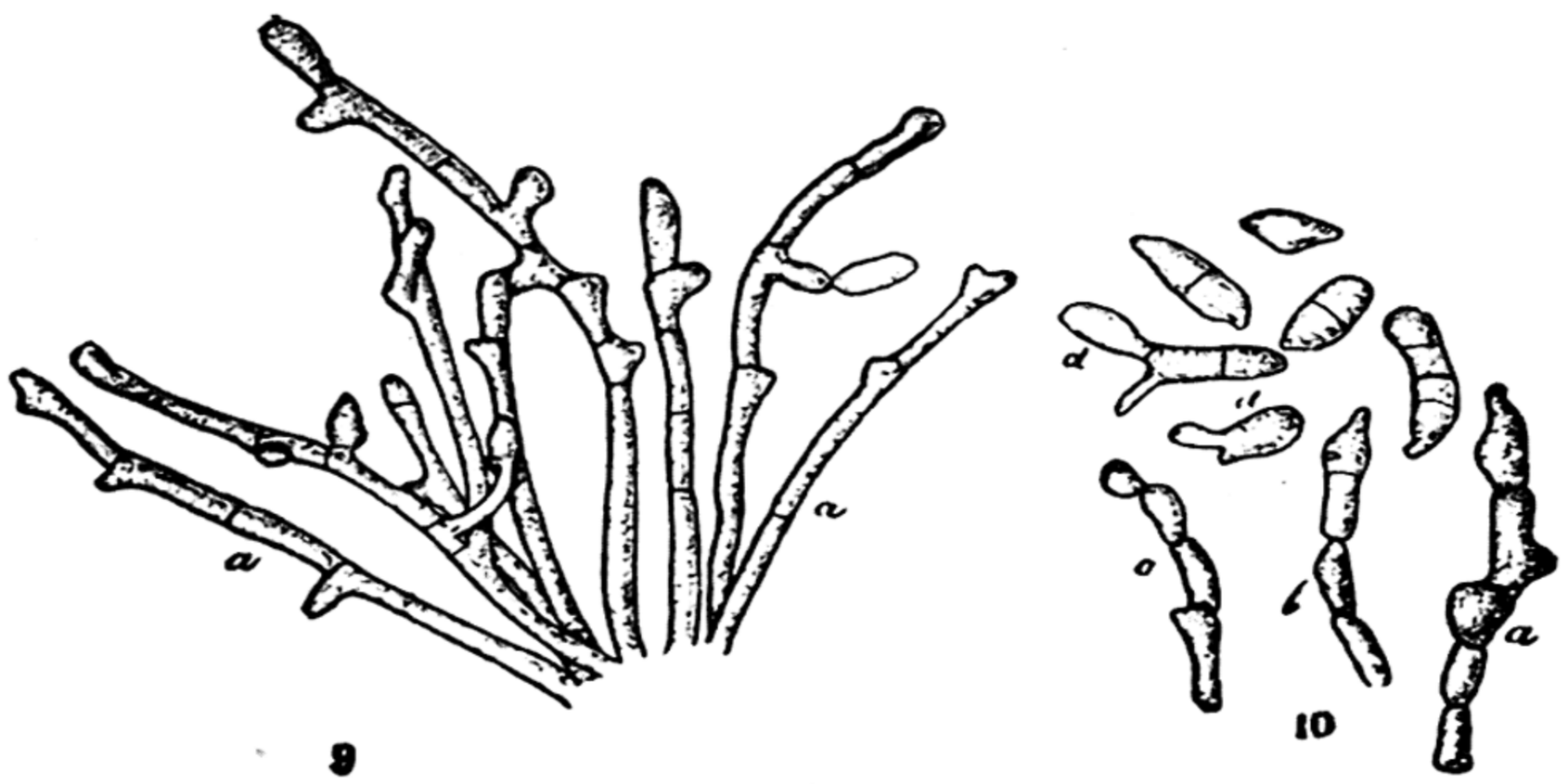


FIG. 407.—C. fulvum. After Southworth.

what flexuose, brown; conidia oblong, oblong-ovate, 2 to several septate, obtuse, pale brown.

On spinach leaves in New Jersey, causing disease.

C. graminum Cda.

Clusters minute, irregular, scattered, greyish-brown; conidiophores distinct, erect, simple, nodulose-flexuose, brown; conidia concolorous, continuous to several-celled, rounded or oblong.

It is reported that this fungus was commonly present on sterile wheat florets and that inoculation with it increased such sterility slightly.

C. oryzæ S. & Sy. is on rice;

C. orchidis C. & M. on Oncidium;

C. pisi Cu. & Ma. on Pisum.

C. peoniæ Pass.

Spots large, chestnut brown, hyphæ short, simple; spores various, long, 1 to 2-septate. On peony.

C. epiphyllum Mart. is on oak, sycamore, poplar, etc.;

C. juglandis Cke. on walnut;

C. scribnerianum Cav. on beech;

C. hypophyllum Fcl. on elm;

C. tuberum Cke. on sweet potato tubers;

C. scabies Cke. on tomato and cucumber;

C. oxycocci Sh. on cranberry.

C. zeæ Pk.

Sterile hyphæ hyaline, sub-cutaneous, erumpent; spores elliptic-oblong, 4 x 20 μ, continuous or 1 to 3-septate.

In immature corn grains.

C. brunneo-atrum McA. is on orange leaves and young shoots in Australia;

C. javanicum Wak. on sugar cane in Java causing root molds.

Polythrincium Kunze & Schmidt (p. 602)

Conidiophores erect, fasciculate, regularly flexuose or torulose, black, simple; conidia acrogenous, obovoid.

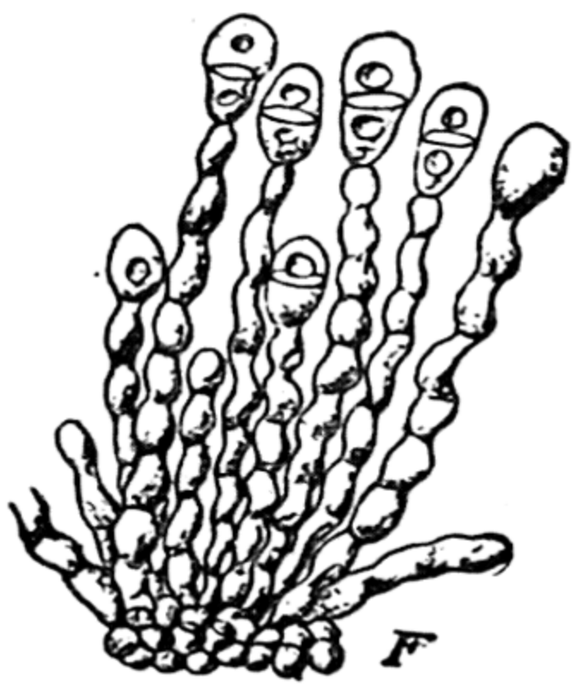


FIG. 408.—P. trifolii. After Corda.

Monotypic. In part=Phyllachara. See p. 220.

P. trifolii Kze. on clover=Phyllachora trifolii. See p. 220.

Fusicladium Bonardin (p. 602)

Conidiophores short, erect, straight, sparingly septate, subfasciculate, olivaceous; conidia ovoid or subclavate, continuous or 1-septate, acrogenous, solitary or paired.

In part=Venturia and Phyllachora.[220, 253]

Over forty species, several pathogenic.

F. fraxini Aderh. on Ash.=V. fraxini. See p. 255.

F. saliciperdum (All. & Pub.) Land. on Salix=V. chlorospora. See p. 255.

F. cerasi (Rab.) Sacc. on cherry, peach,=V. cerasi. See p. 255.

F. pirinum (Lib.) Fcl. on pear=V. pirinia. See p. 253.

F. dendriticum (Wal.) Fcl. on pomaceous fruits=V. inæqualis. See p. 253.

F. orbiculatum Thüm on Sorbus=V. inæqualis var. cinerascens. See p. 255.

F. depressum (B. & Br.) Sacc. on Umbelliferæ=Phyllachora.

F. betulæ Aderh. on birch=V. ditricha. See p. 255.

F. tremulæ Fr. on aspen=V. tremulæ. See p. 255.

F. fagopyri Oud. is found on buckwheat;

F. lini Sor. on Linum.

F. eriobotryæ Cav. attacks leaves of Eriobotrys.[297]

F. destruens Pk.

Conidiophores short, 20–50 μ, fasciculate, continuous or 1 to 2-septate, basally, colored, clusters slightly olive-green; conidia acrogenous, continuous or 1-septate, subcatenulate, ellipsoid to oblong, colored, 7–20 x 5–7 μ.

On oats.

F. effusum Wint.[298]

Spots minute, rounded, rarely effused, confluent, smoky; conidiophores erect, simple or slightly branched, septate, torulose, brownish, lighter above, 100–140 x 4 μ; conidia oblong fusoid to rhomboid, continuous or uniseptate, light fuscous, subtruncate, 17–24 x 5.5–7 μ.

It constitutes the pecan scab affecting the leaves, stems and nuts.

F. vanillæ Zim. is on vanilla.

An undetermined species is the cause of a black canker of Hevea.

Passalora Fries & Montaigne (p. 602)

Conidiophores filiform, intricate multiseptate, olive; conidia oblong to fusoid, acrogenous.

A small genus quite similar to Fusicladium except for the pluriseptate conidiophores.

P. bacilligera M. & F. and **P. microsperma** Fcl. occur on Alnus.

Scolecotrichum Kunze & Schmidt (p. 602)

Conidiophores short, subfasciculate, olive; conidia oblong or ovate, pleurogenous or acrogenous.

A genus of some thirty species very similar to Fusicladium.

S. graminis Fcl.

Spots foliicolous, elongate, ochraceous; conidiophores densely fasciculate, filiform, simple, sinuose, 90–100 x 6–8 μ, subcontinuous; conidia fusoid-obclavate, 35–45 x 8–10 μ, uniseptate, olive-brown.



FIG. 409.—S. graminis. After Saccardo.

It is common, causing leaf spots on grasses, especially on Avena and Phleum. It is described on the latter by Trelease.[299] The mycelium collects below the stomata and pushes its tuft of hyphæ through them.

S. melophthorum P. & D. parasitizes melons and cucumbers in France;[300]

S. fraxini Pass. is on ash.

S. iridis F. & R. is on Iris;

S. musæ on banana.

S. avenæ Erík. is on oats.

Dematiaceæ-Phragmosporæ (p. 594)

Conidia 2 to many-celled, dark, rarely light or hyaline, ovoid to cylindric or vermicular.

KEY TO GENERA OF Dematiaceæ-Phragmosporæ

Fertile hyphæ very short or little different from the conidia
  Conidia not in chains
    Conidia muticate
      Conidia united at base, fasciculate, cylindric. ..... 1. **Cryptocoryneum.**
      Conidia separate
        Conidia straight ovoid to cylindric
          Conidia solitary ..... 2. **Clasterosporium,** p. 609.
          Conidia in bundles ..... 3. **Stigmina,** p. 610.
        Conidia fusoid-falcate. ..... 4. **Fusariella.**
    Conidia cuspidate or setose
      Hyphæ dichotomous and broadened at apex. ..... 5. **Urosporium.**
      Hyphæ not dichotomous or broadened. ..... 6. **Ceratophorum,** p. 610.
  Conidia in chains

Conidia not connected by isthmi..... 7. **Septonema.**
Conidia connected by isthmi. ..... 8. **Polydesmus.**
Fertile hyphæ distinctly different from the conidia
Conidia solitary or nearly so, acrogenous for the most part
Conidia muticate. ..... 9. **Helminthospora.**
Conidia echinulate. ..... 10. **Heterosporium,** p. 610.
Conidia smooth
Hyphæ creeping, radiate. ..... 11. **Ophiotrichum.**
Hyphæ short, ascending or erect, conidia ovoid to oblong ..... 12. **Napicladium,** p. 611.
Hyphæ longer, rigid; conidia ovoid to elongate
Conidia ovoid..... 13. **Brachysporium.**
Conidia elongate..... 14. **Helminthosporium,** p. 611.
Hyphæ flexuous, pannose.... 15. **Drepanospora.**
Conidia 1 to 3-ciliate at apex..... 16. **Camposporium.**
Conidia verticillate or capitate
Hyphæ dark
Conidia acrogenous, forming a head
Hyphæ simple. ..... 17. **Acrothecium.**
Hyphæ branched at the apex. 18. **Atractina.**
Conidia pleurogenous, somewhat verticillate
Hyphæ rostrate and naked at apex. ..... 19. **Rhynchomyces.**
Hyphæ not rostrate at apex. . 20. **Spondylocladium,** p. 614.
Hyphæ hyaline or bright colored, apex denticulate..... 21. **Neomichelia.**
Conidia catenulate as a rule
Conidia arising from the interior of the hyphæ . . .. IV. **Sporoschismeæ.**
Conidia arising from the apex, sometimes solitary. ..... V. **Dendryphieæ,** p. 615.

Clasterosporium Schweinitz (p. 608)

Hyphæ creeping, here and there swollen, erect, bearing 2 to several-septate, solitary, apical conidia.

A genus of some seventy-five species.

C. glomerulosum Sacc. on Juniperus leaves is often reported as Sporodesmium glomerulosum.

C. carpophilum (Lév.) Aderh.[58, 301, 302, 423] Aderhold by inoculations, properly controlled, showed this fungus capable of causing gummosis of prunaceous hosts though C. herbarium did not do so.

Effuse, hyphæ simple or short-branched, densely aggregated, septate, conidia elongate-fusoid, obtuse, 4 to 5-septate, slightly constricted at the septa. It is commonly seen as the cause of a brown spot on peaches. Spores do not appear in the young spots but are found sparingly in older brown areas.



Fig. 410.—Stigmina. After Saccardo.

Pure culture inoculations by Stewart[58] on peach twigs resulted in blackening and gummosis.

C. amygdalearum (Pass.) Sacc. is also described on rosaceous hosts. It is perhaps identical with C. carpophilum and may be connected with Pleospora vulgaris.[371]

C. putrefaciens (Fcl.) Sacc. causes spots on leaves of the sugar-beet.

Stigmina Saccardo (p. 608)

Hyphæ epiphyllous; conidiophores very short or obsolete; conidia ovate or elongate, 3 or more-celled, aggregated.

S. briosiana Far. causes disease of apricots in Europe.

Ceratophorum Saccardo (p. 608)

Hyphæ creeping, scant; conidiophores short, erect; conidia fusoid or cylindric, 2 to many-septate, dark or reddish-brown.

A small genus.

C. setosum Kirch. is found on leaves and shoots of young plants of Cytisus, etc., in greenhouses;[303]

C. ulmicolum E. & K. on Ulmus leaves.

Heterosporium Klotzsch (p. 609)

Hyphæ subcespitose, smoothish, often branched; conidia oblong, 2 to several-septate, smoothish to granular or echinulate.

A genus of forty species or more.

H. echinulatum (Berk.) Cke.[21, 304]

Spots gregarious, on fuscous areas; conidiophores fasciculate from a stromatic base, 150–200 x 8 μ, rarely shorter, flexuose-nodose, fuliginous; conidia at the nodes, oblong-cylindric, rounded at the ends, 2 to 3-septate, 40–50 x 15–16 μ, slightly constricted, roughened, brownish.

It causes a destructive mold on carnation leaves and stems. The first epidemic was noted by Sorauer in Berlin in 1883.

H. gracile (Wal.) Sacc. was determined to be the cause of disease of Iris, Narcissus and other Monocotyledons.[305]

H. variable Cke.[306]

Conidiophores flexuose, slender, more or less nodulose at the septa; conidia cylindric oblong, 2 to 4-septate, minutely warted, 20–25 x 7–10 μ, pale olive. On spinach.

Other parasitic species are:

H. ornithogali Klotz. on Liliaceæ;

H. laricis C. & M. on larch leaves;

H. auriculi Mas. on cultivated Auricula;

H. syringæ Oud. on lilac leaves.[22]

H. minutulum C. & M. causes disease of hops.

Napicladium von Thümen (p. 609)

Conidiophores short, subfasciculate, smoothish; conidia acrogenous, solitary, large, oblong, 2 to many-septate, smoothish.

A small genus.

N. janseanum Rac. is on rice.

N. soraueri is a form of Venturia inæqualis with somewhat atypical napiform spores. See p. 253.

Helminthosporium Link (p. 609)

Conidiophores erect, rigid, subsimple, fuscous; conidia fusoid to elongate-clavate or cylindric, pluriseptate, fuscous, smooth.

In part=Pleospora. See p. 259.

About two hundred species; several are important pathogens, others saprophytes.

The species show biologic differentiation into races similar to

that exhibited in the Erysiphaceæ, though morphologically they may be inseparable.

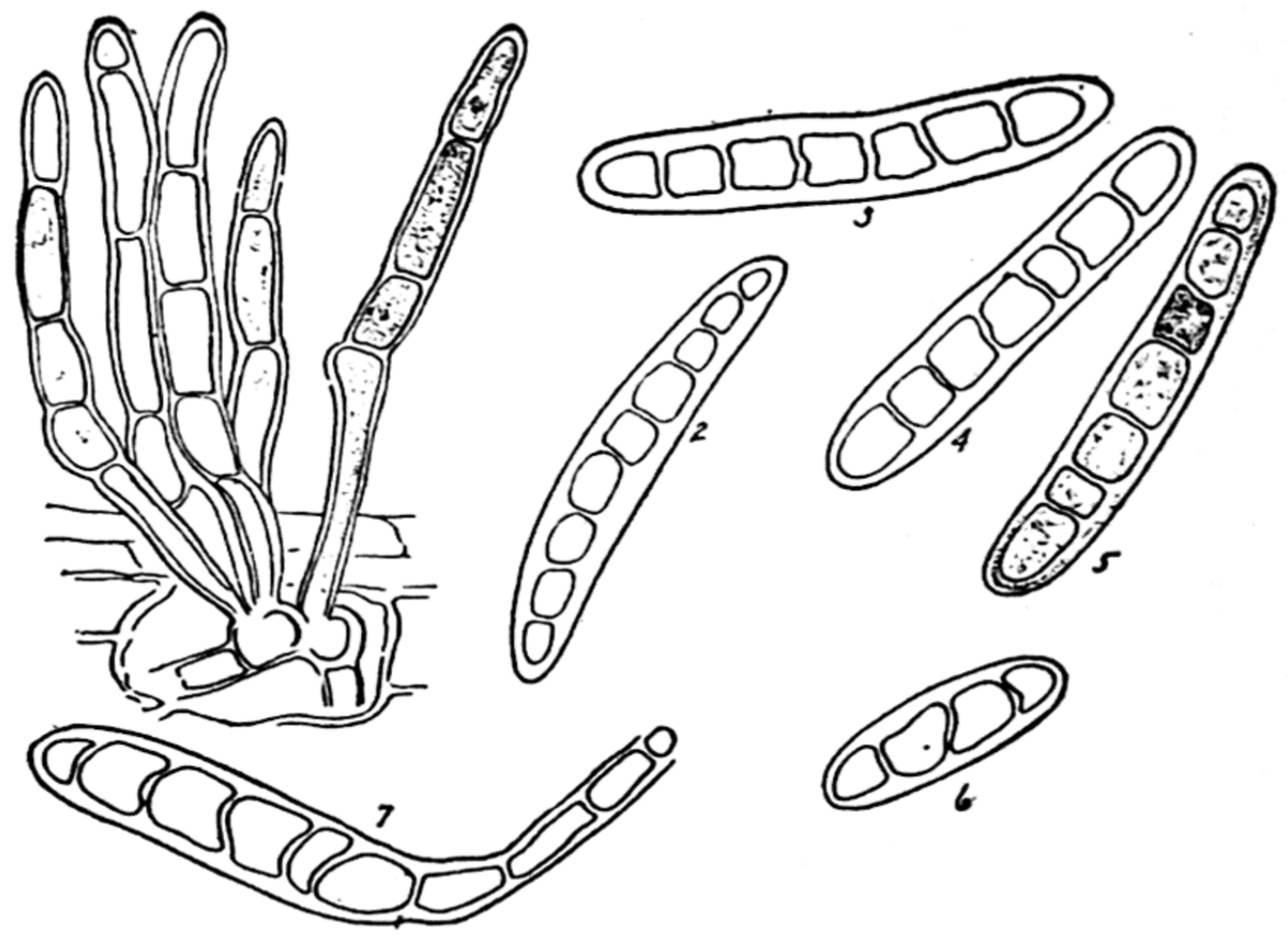


FIG. 411.—Helminthosporium gramineum. Conidiophores and spores. After King.

H. gramineum (Rab.) Erik. on grasses=Peleospora gramineum. See p. 261.

H. trichostoma=Pleospora trichostoma. See p. 260.

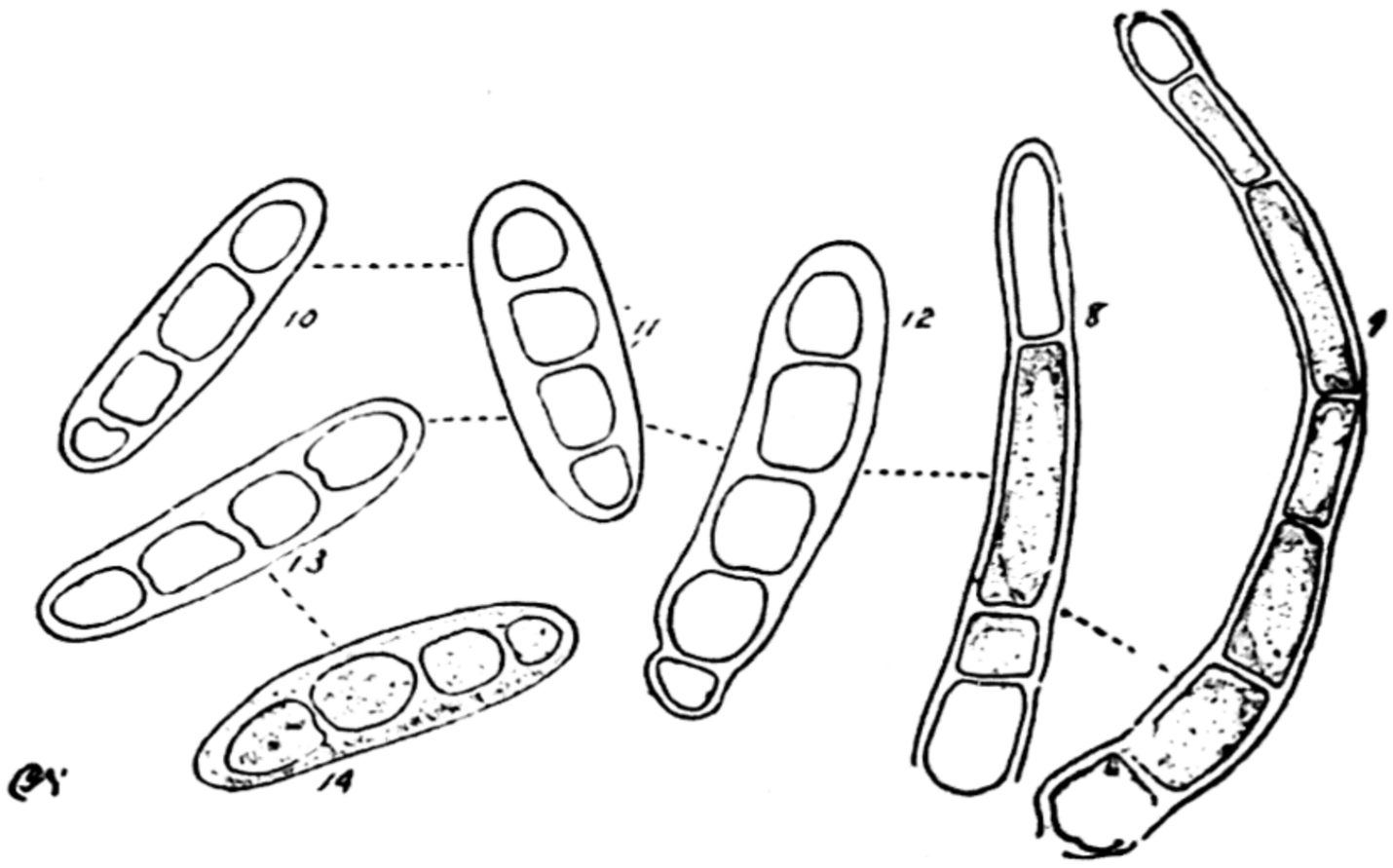


FIG. 412.—Helminthosporium teres. Conidiophores and spores. After King.

H. teres Sacc.

Spots oblong, olive, amphigenous; conidiophores fasciculate, often crooked and nodulose, septate, brown, 100–130 x 12 μ;

conidia acrogenous, straight, cylindrical, ends rounded, 4 to 5-septate, not constricted, dark olive-brown, 100–115 x 14–18 μ. On oats and barley.

H. avenæ Ei.

Similar to H. teres, but the conidiophores scattered, 150–200 x 9–12 μ, septate, brown; conidia cylindric, brownish, 4 to 6-septate, 80–100 x 15–16 μ. On oats.

The conidia of the two last species infect grains and seedlings. The conidia spread the disease from the early infection centers to other parts of the plants but the mycelium remains local.

H. bromi Died. on Bromus=Pleospora bromi, see p. 261.

H. tritici-repentis Died.=Pleospora tritici-repentis, see p. 262.

H. sativum (P.) K. & B.[307]

Mycelium branched, septate; conidiophores fasciculate, fuscous, brown, septate, 8–10 μ wide, sometimes swollen between the septa; conidia solitary, apical, dark brown, 6 to 11-septate, 105–130 x 15–20 μ.

The cause of a destructive late blight of barley from Iowa to Saskatchewan. The disease manifests itself by dark colored, elongate spots on the leaves. It also occurs on the glumes and spikelets, sometimes even penetrating the grains.

H. sorokinianum Sacc. is reported on wheat and rye in Russia;

H. tritici Hen. on wheat in Africa; **H. sigmoideum** Cav. on rice in Italy; while several species are recorded on bamboo.

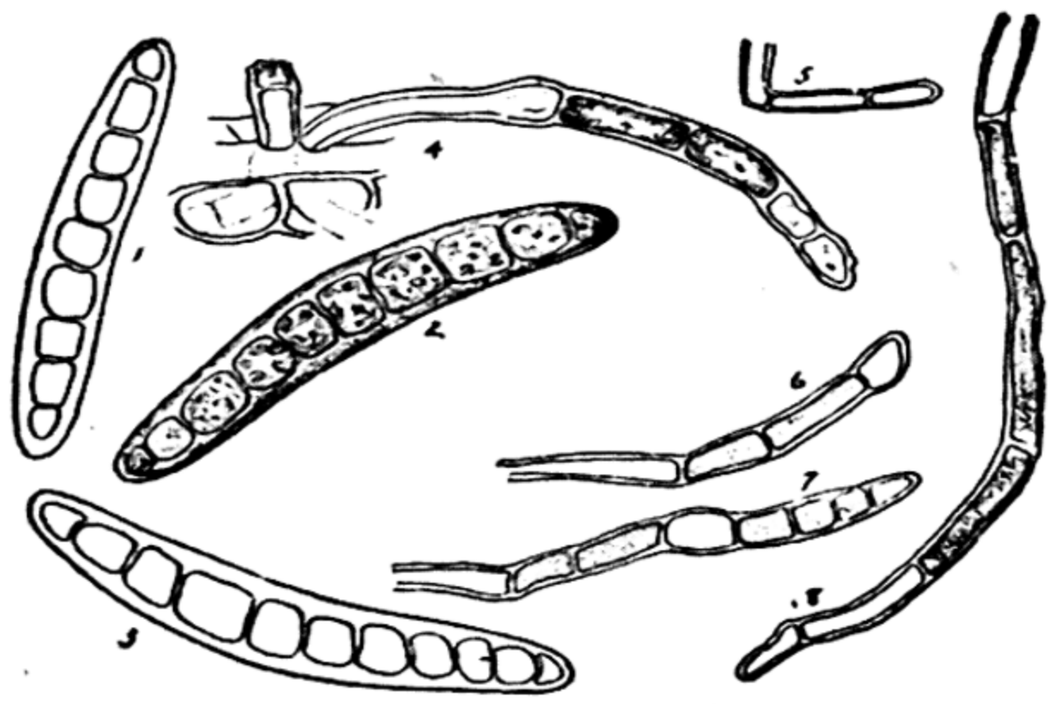


FIG. 413.—Helminthosporium sativum from barley, spores and conidiophores. After King.

H. turcinum Pass.

Spots, large, dry, brownish; conidiophores, gregarious to fasciculate, septate, 150–180 x 6–9 μ, pale olive, apex almost hyaline, often nodulose; conidia spindle-shaped, acute, 5 to 8–septate, pale olive, 80–140 x 20–26 μ.

It produces spots on corn and sorghum in Europe and America.

H. inconspicuum C. & E.[33, 308-310]

Conidiophores elongate, septate, nodose, pale brown; conidia lanceolate, 3 to 5-septate, 80–120 x 20 μ, smooth.

It has been reported on sweet corn from Long Island by Stewart.



FIG. 414.—Helminthosporium inæqualis. After Shear.

H. gramineum, H. turcinum and H. inconspicuum are closely related, possibly identical.

Johnson [310] concludes that H. gramineum with its ascosporic stage includes Piricularia grizea, P. oryzæ, Helminthsporium oryzæ and H. turcinum.

H. inæqualis Sh.

Sterile hyphæ effuse, much branched, dark brown; conidiophores erect, septate, variable in length, 6–8 μ in diameter; conidia both terminal and lateral, more or less curved, 3 to 5-celled, thick-walled, brown, 23–32 x 11–14 μ.

On cranberry.

H. heveæ Petch. is on Para rubber;

H. theæ Bernard on tea in India;

H. iberidis Poll. on Iberis and **H. lunariæ** Poll. on Lunaria, both in Italy.

Spondylocladium Martius (p. 609)

Hyphæ creeping, septate; conidiophores erect, simple, rigid; conidia verticillate, fusoid, usually 3-celled, brownish.

A small genus.

S. atrovirens Harz.[22]

Conidiophores solitary or clustered, cylindric, septate, dingy, olive or brownish, up to 400 μ high; conidia elongate, ovate, apex narrowed, 5 to 7-septate, concolorous with the conidiophores, 30–50 x 6–9 μ.

On potatoes this fungus causes blackish to olive spots soon depressed, 2–3 cm. across, which are beset with small black sclerotia and followed by dry rot. According to Appel & Laubert [311] the sclerotia develop whorls of conidiophores. The species is said to occur in the British Isles, the Continent and in America.[312] Its sterile mycelium has been described under the name Phellomyces.[218]



FIG. 415. — S. atrovirens. After Massee.

Dendryphium Wallroth (p. 609)

Hyphæ creeping or obsolete; conidiophores erect, with short apical branches; conidia cylindric, 2 to many-septate, catenulate, brown.

Some thirty or more species.

D. comosum Wal. is the cause of a cucumber leaf spot in England.

Dematiaceæ-Dictyosporæ (p. 594)

Conidia dark, rarely light, muriform, globose to oblong.

Key to Genera of **Dematiaceæ-Dictyosporæ.**

Hyphæ very short or scarcely different from the conidia..... **I. Micronemeæ.**

Conidia not in chains

Conidia not appendaged

Conidia irregularly muriform or sarciniform

Conidia with a conic point at each side..... **1. Oncopodium.**

Conidia without conic points

Conidia globose to oblong

Conidia ovoid to oblong, loose **2. Sporodesmium,** p. 616.

Conidia globose to ovoid, aggregated..... **3. Stigmella.**

Conidia sarcinæform, often coalescent..... **4. Coniothecium,** p. 617.

Conidia as if composed of parallel chains of cells

Chains of conidia never separating..... **5. Dictyosporium.**

Chains of conidia separating..... **6. Speira.**

Conidia corniculate at apex..... **7. Tetraploa.**

Conidia in chains, often asperate or with isthmi..... **8. Sirodesmium.**

Hyphæ distinctly different from the conidia **II. Macronemeæ.**

Conidia of the same form

Conidia not in chains or capitate

Conidia bearing little conidia on their surfaces..... **9. Xenosporium.**

Conidia single
Hyphæ alike
Conidia cruciate-divided, verrucose. ..... 10. **Tetracoccosporium.**
Conidia muriform, typically smooth
Hyphæ decumbent. ..... 11. **Stemphylium,** p. 617.
Hyphæ erect or ascending
Conidia globose, pleurogynous
Conidia around the apex of the hyphæ..... 12. **Coccosporium.**
Conidia conglobate around the base..... 13. **Trichægum.**
Conidia ovoid to oblong, mostly acrogenous
Conidiophores somewhat lax, colored. ..... 14. **Macrosporium,** p. 618.
Conidiophores rigid, very dark. ..... 15. **Mystrosporium,** p. 620.
Hyphæ of two kinds, longer sterile, shorter fertile..... 16. **Septosporium,** p. 620.
Conidia capitate. ..... 17. **Dactylosporium.**
Conidia catenulate
Hyphæ velvety, erect, subsimple; conidia caudate..... 18. **Alternaria,** p. 621.
Hyphæ crustose, various; conidia 2-celled; conidia-like ganglia sarcinæform ..... 19. **Fumago,** p. 624.
Conidia of two forms, dark sarcinæform and subhyaline falcate..... 20. **Sarcinella,** p. 625.

Sporodesmium Link.[313] (p. 615)

Mycelium and conidiophores poorly developed; conidia ovoid oblong, subsessile or short-stalked, rather large, clathrate-septate, fuligineus.

Over eighty species.

S. piriforme Cda. on oranges=Pleospora hesperidearum, p. 260.

S. exitiosum Kühn on crucifers=Leptosphæria napi, p. 258.

S. exitiosum var. **solani** Schenck is reported as the cause of a potato disease.

S. solani-varians Vanha is the cause of potato disease in Europe, the foliage bearing brown spots and finally dying in a manner resembling death caused by Phytophthora. Cladosporium and pycnidial forms are said to exist.

S. mucosum Sacc. was reported by Aderholt on cucumber fruit and leaves causing disease.

S. scorzoneræ Aderh. causes a salsify stem and leaf disease.[314]

Other parasitic species are:

S. melongena Thüm. on egg plant;

S. dolichopus Pass. on potato leaves in Italy;

S. ignobile Karst. on asparagus;

S. putrefaciens Fcl. on beet;

S. brassicæ Mas. on Brassica in Bengal.

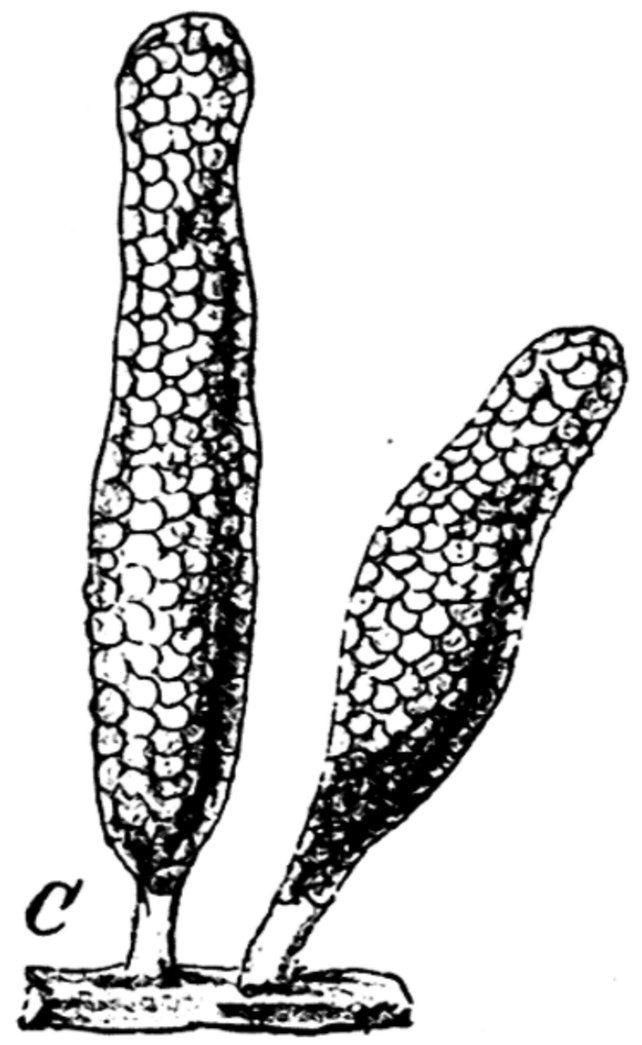


FIG. 416.—Sporodesmium antiquum. After Saccardo.

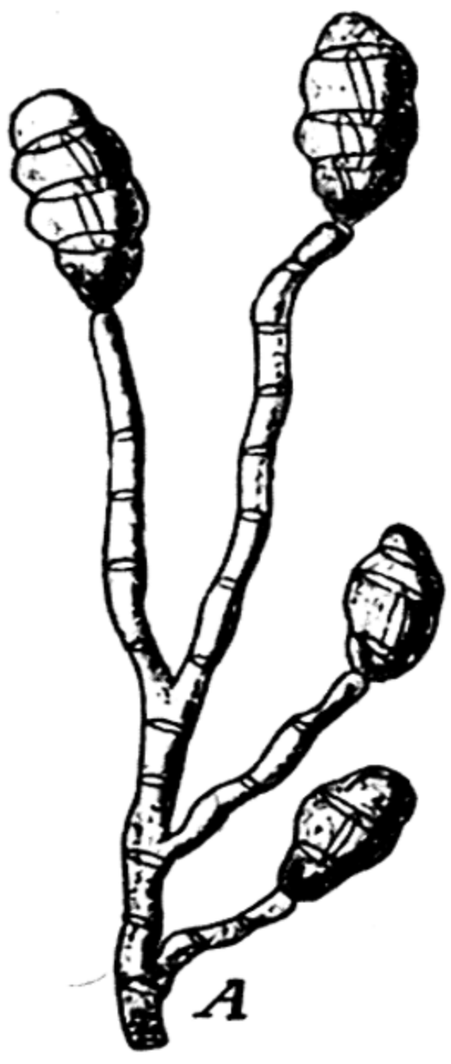


FIG. 417.—Stemphylium. After Saccardo.

Coniothecium Corda (p. 615)

Hyphæ obsolete or poorly developed; conidia gemmiform in origin, variously septate.

Over fifty species of very simple parasitic or saprophytic fungi.

C. chomatosporum Cda. resembling apple scab in its effect is noted as common in Tasmania[138] and Australia.[442]

Stemphylium Walroth (p. 616)

Conidiophores decumbent, intricately branched, hyaline or smoky; conidia acrogenous, ovoid to subglobose, 2 to many-muriform-septate, fuligineus.

Over thirty species.

S. ericoctonum B. & deB. is parasitic on Erica in green-houses.

S. citri Pa. & Ch.[23]

Vegetative mycelium long, hyaline, becoming dark, 4 μ in diameter, septate; conidiophores short; conidia dark brown, subglobose to oblong, apiculate, irregularly muriform, 20–30 x 12–15 μ, usually in chains of three.

This was found associated with an end-rot of oranges from Arizona. Inoculated in pure culture in oranges the fungus developed well. It is perhaps the cause of the disease.

S. tritici Pa.

Hyphæ irregularly branched; conidiophores closely septate, 4–5 μ in diameter; conidia catenulate, irregular, usually clavate, constricted slightly at the septa, 24–35 x 12–15 μ, vermiculate, fuligineus, isthmus short, 3–4 μ in diameter. It is described as the cause of floret sterility of wheat.[295, 296, 316, 435]

Macrosporium Fries (p. 616)

Conidiophores fasciculate, erect or not, more or less branched, colored; conidia usually apical, elongate or globose, dark-colored.

In part=Pleospora. See p. 259.

About one hundred eighty species, many of them saprophytes while others are important pathogens.

M. commune Rab.=M. sarcinula parasiticum Thüm. on various grasses=Pleospora herbarium.[317, 318] See p. 260.

This is reported by Thaxter [317] as the common black mold which follows Peronospora on the onion and which occurs often also on onions not so diseased, being especially common on the seed stalks. It is usually associated with injured plants and may be important only as a wound parasite.

M. porri E.[317]

Effuse, fuligineus; hyphæ short, simple, subfasciculate; conidia elongate-clavate, basally attenuate, multiseptate, 150–180 x 12–20 μ.

It is common on seed onions, less common on market onions. The dark mycelium penetrates the host in all directions and finally produces stromata below the stomata and sends up short hyphæ.

M. alliorum C. & M. is also on onion; [33]

M. hurculeum E. & M.

Amphigenous on rounded, grey spots; conidiophores erect, ces-

pitose, flexuose, brown, few septate, 70–80 x 5 μ; conidia brown, multiseptate, clavate, 200–225 x 21–26 μ.

It causes leaf spots on turnips, horse radish and other crucifers.

M. brassicæ Berk.

Mycelium inconspicuous, conidia clavate, antennæform, 5 to 11-septate, 50–60 x 12–14 μ.

It is a common cause of black mold on cabbage, collards and other crucifers.

M. ramulosum Sacc. is on celery.

M. catalpæ E. & M.[34]

On brownish spots; conidiophores brown, curved, nodose, 8 to 12-septate, erect, amphigenous, 90–135 x 6 μ; conidia brown, obovate to pyriform, submuriform, 27–54 x 15–27 μ.

Producing leaf spots on Catalpa in company with Phyllosticta catalpæ.

M. nobile Vize. is on Dianthus.

M. iridis C. and E. and **M. aductum** Mas. are on iris;

M. cheiranthi (Lib.) Fr. on Cheiranthus.

M. tabacinum E. & E.[319] causes thin, white amphigenous spots, 2–3 mm. with a narrow dark border; conidiophores effused, 35–45 x 3–4 μ, septate and torulose above; conidia obovate, 15–25 x 10–12 μ, sessile or short stipitate, usually 3-septate.

It is reported to cause white leaf spots on tobacco.

M. longipes E. & E.

On concentric, rusty brown, amphigenous spots, 3 to 5 mm. in diameter; conidiophores effused, amphigenous, slender, 40–70 x 3–4 μ, septate, often contracted at the septa, erect and more or less torulose above; conidia clavate, 40–50 x 15–20 μ, 3 to 7-septate, attenuate below into a distinct stipe. On tobacco.

M. sarciniforme Cav. is reported by Walkoff[321] on red clover in Germany where it causes the leaves to dry and die.

M. nigricanthium Atk.[322]

Amphigenous; condiophores subfasciculate or scattered nodose, septate, olive-brown, 50–140 x 6–7 μ; conidia olive-brown, constricted about the middle, rostrate at one side of the apex, 18-22 x 36–50 μ. On cotton.

M. cucumerinum E. & E.[323,324]

Epiphyllous on orbicular, subconfluent, brownish spots, 3–4

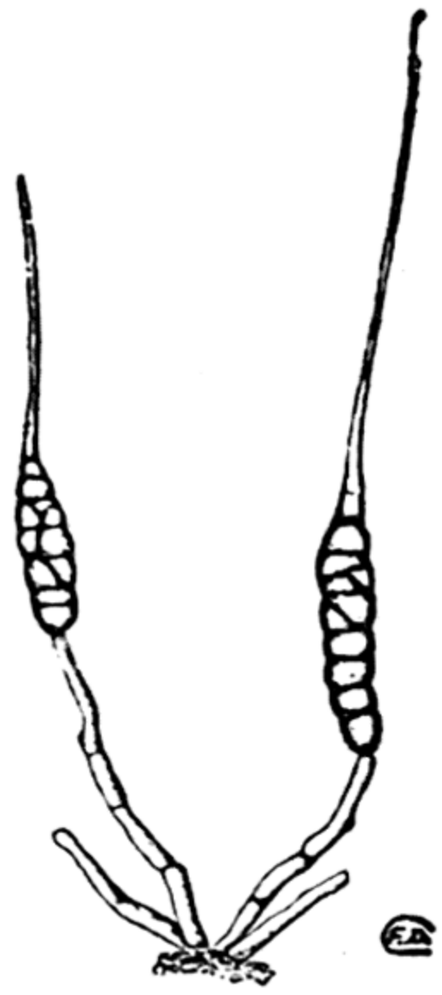


FIG. 418.—Macrosporium cucumerinum on canteloupe. After Chester.

mm. in diameter; conidiophores fasciculate or solitary, subgeniculate, 1 to 3-septate, 35–50 x 5–6 μ; conidia clavate, slender-stipitate, 3 to 8-septate, somewhat constricted, submuriform, 30–75 x 15–25 μ; pedicel 25–35 μ long.

On leaves, stems and fruits of cantaloupes.

M. cladosporioides Desm. is on beet, lettuce, onion and many other hosts.

M. verrucosum Lutz. occurs on cacao;

M. gramineum Cke.[325] on sugar cane.

M. uvarum Thüm. is reported on Vitis;

M. violæ Poll. on violets in Italy;

M. saponariæ Pk. on Saponaria.

M. macalpinianum S. &. Sy. is injurious to Pelargonium.

Mystrosporium Corda (p. 616)

Conidiophores simple or sparingly branched, short, septate, fuscous, rigid; conidia elliptic, subglobose or oblong, pluriseptate, muriform, dark, usually solitary, acrogenous.

Some twenty species.

M. abrodens Nebr. is described as the cause of a very serious grain disease in France.

M. aductum Mas. injures Iris bulbs;

M. alliorum Berk. forms dark spots on onion.

Septosporium Cda. (p. 616)

Conidiophores short, intermixed with longer sterile hyphæ; conidia ovoid to pyriform, fuscous.

A small genus.

S. heterosporium E. & G.

Spots scattered, confluent or not, rusty brown, 0.5–1 cm. in diameter, conidiophores hypophyllous, fasciculate from the stomata; conidia variable, oblong cylindric, constricted at the septa, 20–40 x 5–7 μ, separating into gemmæ.

Reported in 1888 [32] on the wild grape in California.

Alternaria Nees. (p. 616)

Conidiophores fasciculate, erect, sub-simple, short; conidia clavate-lageniform, septate, muriform, catenulate.

In part=Pleospora. See p. 259.

Some thirty or more species, many of pronounced economic importance.

A. sp. on Tropœolum=Pleospora tropœoli. See p. 260.

A. trichostoma Died. on barley=Pleospora trichostoma. See p. 260.

A. forsythiæ Harter.[326]

Hyphæ cespitose, amphigenous; spot concentric zonate: conidia 18–60 x 10 x 16.5 μ.

It causes subcircular leaf spots on cultivated Forsythia.

A. brassicæ (Berk.) Sacc.

Conidiophores short, continuous, short-branched, apically equal, conidia elongate, fusoid, clavate, 60–80 x 14–18 μ, 6 to 8-muriform-septate, olivaceous.

On crucifers.

A. brassicæ (Berk.) Sacc. var. **phaseoli** Brun. occurs on beans in Italy.

A. cucurbitæ Let.[128, 327] may be identical with A. brassicæ.

It was noted by Thaxter in Connecticut causing blight of melons. The black mold is copious in the older circular spots. Pure cultures were obtained and successful inoculations were made on normal uninjured melon leaves.

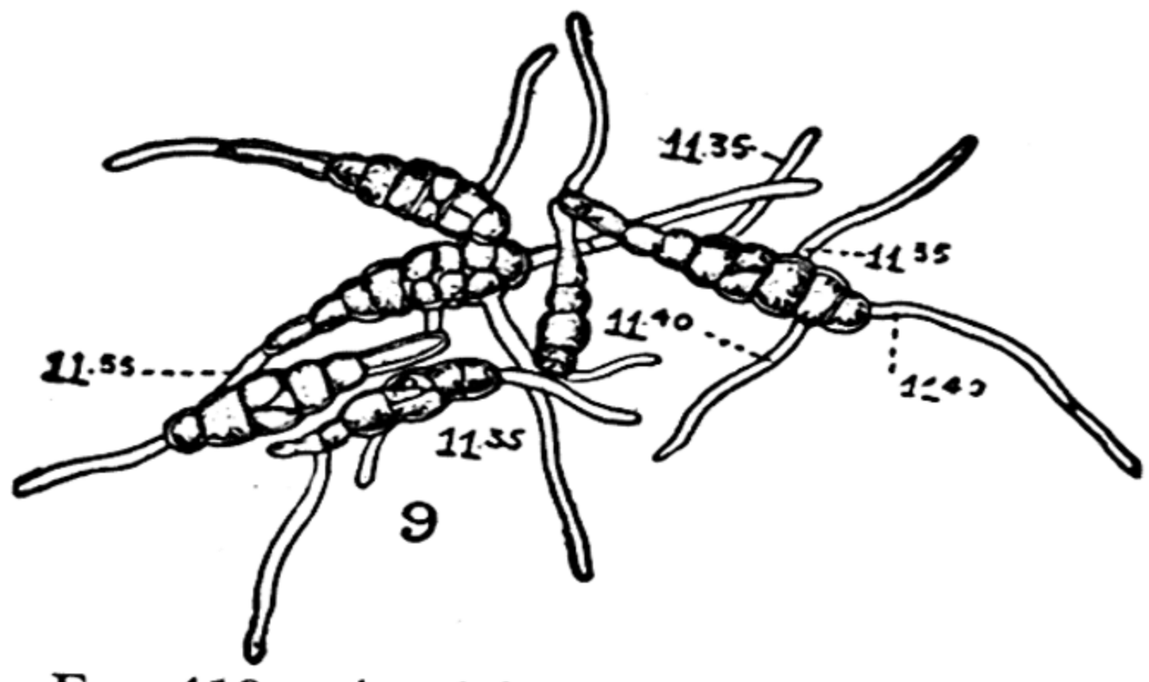


FIG. 419.—A. violæ, germinating spores. After Dorsett.

It is also reported by Selby[128] as the probable cause of muskmelon leaf spots in Ohio, and it is a common source of troubles on various cruciferous hosts.

A. tenuis Nees.[328] is reported by Behrens on tobacco seedlings.

A. violæ G. & D. [329]

Conidiophores erect, pale-olive, septate, simple, 25–30 x 4 μ, conidia in chains at or near the apex of the conidiophore, clavately

flask-shaped, strongly constricted at the septa, olive, 40–60 x 10–17 μ.

Circular leaf-spots are produced on violets. Spores are found on the spots only when conditions are most favorable, i. e., in a humid air. The parasitism of the fungus was demonstrated by inoculation with spores on living leaves in distilled water.

A. panax Whet.[256]

Spots amphigenous, circular, becoming dingy white with a



FIG. 420.—Alternaria. Spores and spore-bearing stalks. After van Hook.

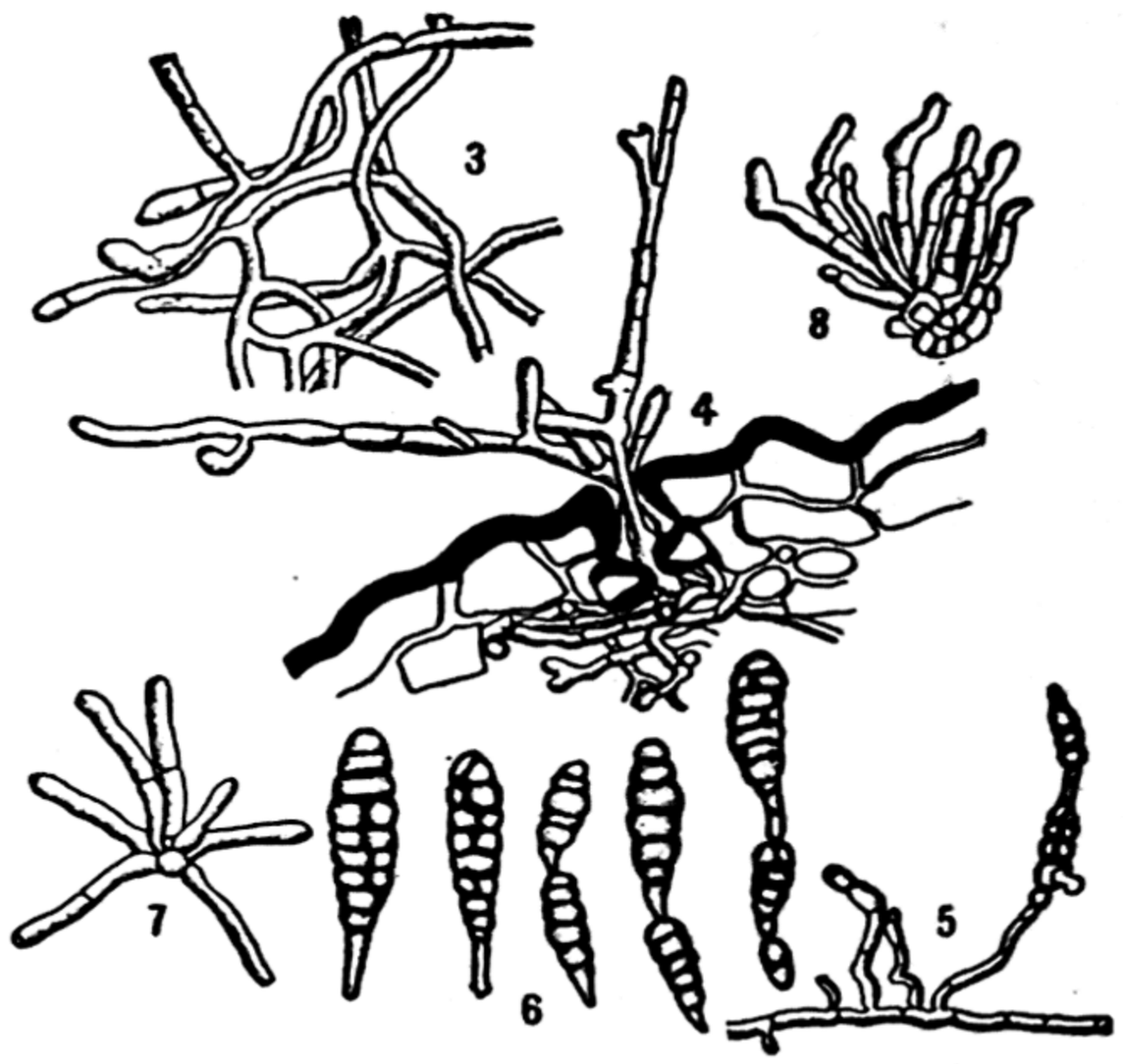


FIG. 421.—A. dianthi. *3*, Mycelium showing branching and septation. *4*, Showing mycelium below stoma and hyphæ emerging through the stoma. *5*, Showing catenulate spores as borne upon hyphæ. *6*, Spores showing shape, septation and catenulation. *7*, A young cluster of hyphæ. *8*, An older cluster of hyphæ. After Stevens and Hall.

reddish-brown margin, covering half the leaflet or less; hyphæ brown, septate, 5–7 μ in diameter; conidiophores erect, tufted, somewhat irregular, especially at the tips, brown, septate, 100–120 x 5–6 μ; conidia brown, in chains of 5 or 6, elliptic to oblong, 45–65 x 15–20 μ.

On ginseng causing leaf blight.

A. dianthi S. & H.[331]

Spots epiphyllous, ashen-white, definite, circular. Conidiophores cespitose from stomata, amphigenous, dark-brown, 1 to 4-septate, erect, 1–25 from a stoma; conidia 26–123 x 10–20 μ, clavate,

tapering, obtuse, basally dark-brown, slightly constricted at the septa, 5 to 9 times cross-septate and 0–5 times longitudinally septate.

It causes injury on carnation leaves and stems.

A. solani (E. & M.) Jones & Grout. [155, 332, 333-337]

Spots brown, circular to elliptic, concentrically zonate, amphigenous, irregularly scattered over the leaf surface; mycelium



FIG. 422.—A. solani, 2, spores germinating and penetrating the living potato leaf; 5, showing catenulation of spores. After Jones.

light-brown; conidiophores erect, septate, 50–90 x 8–9 μ; conidia obclavate, brown, 145–370 x 16–18 μ with 5 to 10 transverse septa, longitudinal septa few, conidia terminating in a very long hyaline, septate beak ½ the length of the conidium or longer.

It causes early blight, a leaf spot disease of potatoes and tomatoes,[332] and is widely prevalent. It was first described in 1882 in America but is now known to be widely destructive.[335] On potatoes it was first recorded by Galloway in 1891. In 1891 also Chester [155] and Galloway [336] proved its pathogenicity by inoculations on

tomato and potato, the spots appeared in eight or ten days after inoculation. Jones, using pure cultures, confirmed the conclusions of Chester and Galloway, the disease spots appearing as early as the third to fifth day after inoculation on vigorous uninjured leaves. The mycelium grows luxuriantly within the leaf but spores do not usually form until after the death of the supporting tissues when the conidiophores emerge through the stomata or by rupturing the epidermis. Often no spores are formed and rarely are many present. The mycelium may live a year or more and resume sporulation the following season.

A. fasciculata (C. & E.) Jones & Grout.[198, 338, 339, 341]

Conidiophores light or dark-brown, becoming almost black, darker than the vegetative hyphæ but like them echinulate, 30–40 x 4–5 μ; conidia concolorous with the conidiophores, 35–66 x 16–20 μ, obclavate, 3 to 6 times cross-septate, 1 to 2 longitudinal septa, apical cell hyaline.

This fungus is associated as a saprophyte with the blossom-end-rot of tomatoes and also causes a serious decay of the ripened fruit. The literature of the disease is rather voluminous and contains a number of synonyms, among them Macrosporium tomato. M. lycopersici, M. rugosa, M. fasciculata. Alternaria solani has also been credited with this disease and indeed the two species may be identical.[339]

A. fici Far. is on figs;

A. tabacinum Hori on tobacco;[15]

A. vitis Cav. on Vitis.

An undetermined Alternaria accompanied by a Macrosporium was constantly found in Nevadillo blanco olives which were shrivelled, particularly at the apex.

These fungi were regarded as the cause of the disease.[342]

Fumago Persoon (p. 616)

Hyphæ decumbent, intricate, frequently pseudo-stromatic, black; conidiophores, erect, branched; conidia ovoid, oblong or sarcinæform, 1 to 2-septate.

A small genus, chiefly conidial forms of Capnodium and Meliola. See pp. 192, 193.

F. camelliæ Cat. on various hosts = Meliola camelliæ. See p. 193.

Sarcinella Saccardo (p. 616)

Hyphæ decumbent, septate, branched, dark; conidiophores much reduced; conidia of two kinds: 1, dark packet-like; 2, subhyaline falcate. Both are intermixed.

A small genus chiefly conidial forms of Dimerosporium. See p. 190.

S. heterospora Sacc. on various hosts = Dimerosporium pulchrum. See p. 191.

Dematiaceæ-Scolecosporæ (p. 594)

Conidia dark or subhyaline, vermiform or filamentose, multiseptate.

There is only one genus.

Cercospora Fries

Conidiophores variable, almost obsolete or well developed, simple or branched; conidia vermiform or filiform, straight or curved, multiseptate, subhyaline to dark.

In part = Mycosphærella. See p. 243.

The genus is a very large one, some seven hundred species, and contains very many aggressive, important parasites, chiefly causing leaf spotting. The spots are often blanched and are rendered ashen colored in the centers by the presence of the dark hyphæ. The hyphæ are usually geniculate at the point of spore production, Fig. 427, and thus old hyphæ bear traces of spores previously borne.

C. cerasella Sacc. on cherries = Mycosphærella cerasella. See p. 245.

C. gossypina Cke. on cotton = Mycosphærella gossypina. See p. 248.

C. circumscissa Sacc.

Spots amphigenous, circular, pallid, dry, deciduous; conidiophores fasciculate, nodulose, brownish, simple; conidia acicular, narrowed apically, attenuate, tinged brown, 50 x 3.5–4 μ.

On various species of Prunus this causes leaf holes.

It is reported as especially serious on the almond.[343]

C. bolleana (Thüm.) Sacc.

Hypophyllous, spots subfuscous to olivaceous; conidiophores fasciculate, filiform, 50–80 x 5–6 μ, non-septate, fuscous; conidia terete, fusoid, 35–40 x 7–8 μ, apically obtuse, somewhat constricted, 1 to 5-septate, olive-green.

On figs causing leaf spotting.[344]

C. viticola (Ces.) Sacc.

Spots amphigenous, subcircular to irregular, 2–10 mm. in diameter, ochraceous, emarginate; conidiophores erect, densely fasciculate, filiform, septate, 50–200 x 4–5 μ, straight, somewhat denticulate, ochraceous; conidia elongate-obclavate, somewhat attenuate, 3 to 4-septate, 50–70 x 7–8 μ, olive-brown.[199]



FIG. 423.—C. concors. 6. Hyphæ emerging through a stoma and twining about hair. After Jones and Pomeroy.

It is apparently an unimportant parasite on grape leaves.

C. rubi Sacc. is on Rubus;

C. fumosa Pass. on leaves of Citrus fruits.

C. moricola Cke. is common on mulberry;

C. musæ Zimm. on banana leaves in Java.

C. rœsleri Sacc. occurs in Europe, causing late injury to the grape.

C. angulata Wint.[113]

Spots roundish, angulate, whitish to cinereous, margined, 1–3 mm. in diameter, often confluent; conidiophores hypophyllous, fasciculate, erect, straight or only slightly flexuose, simple, brownish, few septate, 78–105 x 5 μ; conidia filiform-obclavate, long attenuate, hyaline, 7 to 16-septate, 80–170 x 3.5 μ.

On the currant.

C. oryzæ Miy.[16] is on rice in Japan.

C. concors (Casp.) Sacc.[193, 345]

Spots amphigenous, pale above, whitish beneath, rounded, indefinite; conidiophores fasciculate or single from the stomata, erect, brown, septate, simple, 40–80 μ high; conidia single,

apically variable in form, ovate to elongate, curved, 1 to 5-septate, subhyaline, 15–90 x 4–6 μ.

In America this potato parasite was noted in Vermont in 1905 and study of herbarium material revealed two earlier collections. In Germany it was known in 1854 and it has been seen in many parts of Europe since, sometimes in epidemic form.[347]

Conidia are abundant on the spots on stalks emerging from the stomata. The superior and inferior hyphæ differ considerably in length and branching. Brown bead-like chlamydospores form within the leaf. The mycelium is strictly intercellular. The fungus

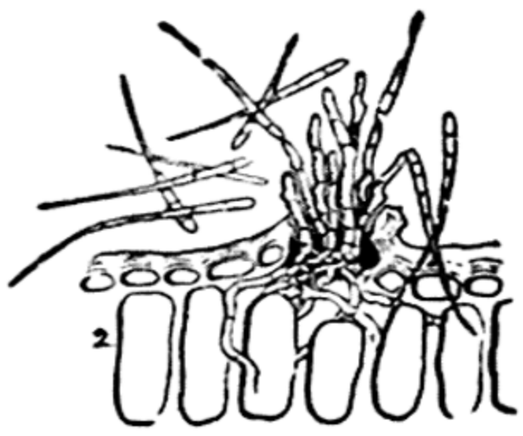


FIG. 424.—C. nicotianæ. After Jones.

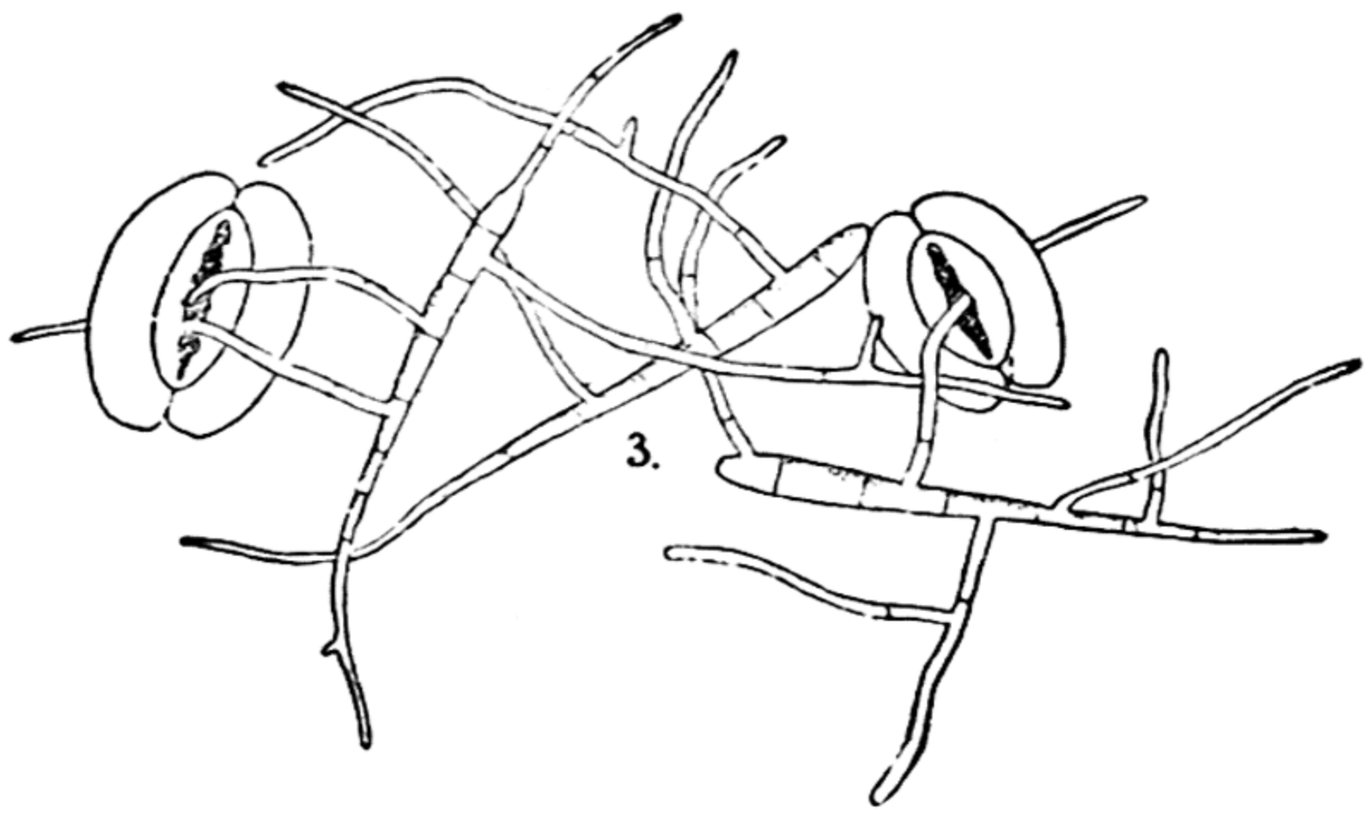


FIG. 425.—C. nicotianæ, spores germinating and entering stomata. After Jones.

was studied in artificial culture by Jones & Pomeroy[193] and inoculations were made, diseased spots appearing about three weeks after inoculation by spraying with suspensions of spores.

C. nicotianæ E. & E.

Spots amphigenous, pale, becoming white, with a narrow and inconspicuous reddish border, 2–5 mm. in diameter, conidiophores amphigenous, tufted, brown, septate, 2 or 3-times geniculate above, simple or sparingly branched, septate, 75–100 x 4–5 μ; conidia slender, slightly curved, multiseptate, 40–75 x 3–3.5 μ, hyaline.

On tobacco it causes leaf spots.[348] The sporiferous hyphæ are abundant near the center of the disease spots.

C. raciborskii S. & Sy. on tobacco in Java and Australia,[349] is a near relative of C. nicotianæ.

C. apii Fr.

Spots amphigenous, subcircular, pale-brown, 4–6 mm. in diameter, with a more or less definite elevated margin; conidiophores hypophylous, light-brown, fasciculate, continuous or 1 or 2-septate, subundulate, 40–60 x 4–5 μ; conidia hyaline obclavate, or almost cylindric, 3 to 10-septate, slender, 50–80 x 4 μ.

A serious leaf spot is produced on celery, parsnips, etc.[350-351]

C. beticola Sacc.[17, 352]

Spots amphigenous, brownish, purple-bordered, becoming ashy centered; conidiophores fasciculate, short, simple, erect, flavous, 35–55 x 4–5 μ; conidia elongate, filiform obclavate, hyaline, multiseptate, 75–200 x 3.5–4 μ.

This fungus, described in 1873, causes a very serious disease of beet producing spots on the leaves. It is common and destructive in America and Europe. The conidiophores usually, though not always, emerge from the stomata from a few-celled stroma and are amphigenous. They vary in length and septation with age. If in humid atmosphere the spots become hoary, due to the large number of spores present. Each cell of the spore is capable of germination. The germ tubes infest the host through the stomata. Pure cultures of the fungus may readily be secured by the usual methods. Here the mycelium produces dense matted colonies of deep olive color and a greenish-grey aërial growth but no conidia. Found also on Spinach in Texas.

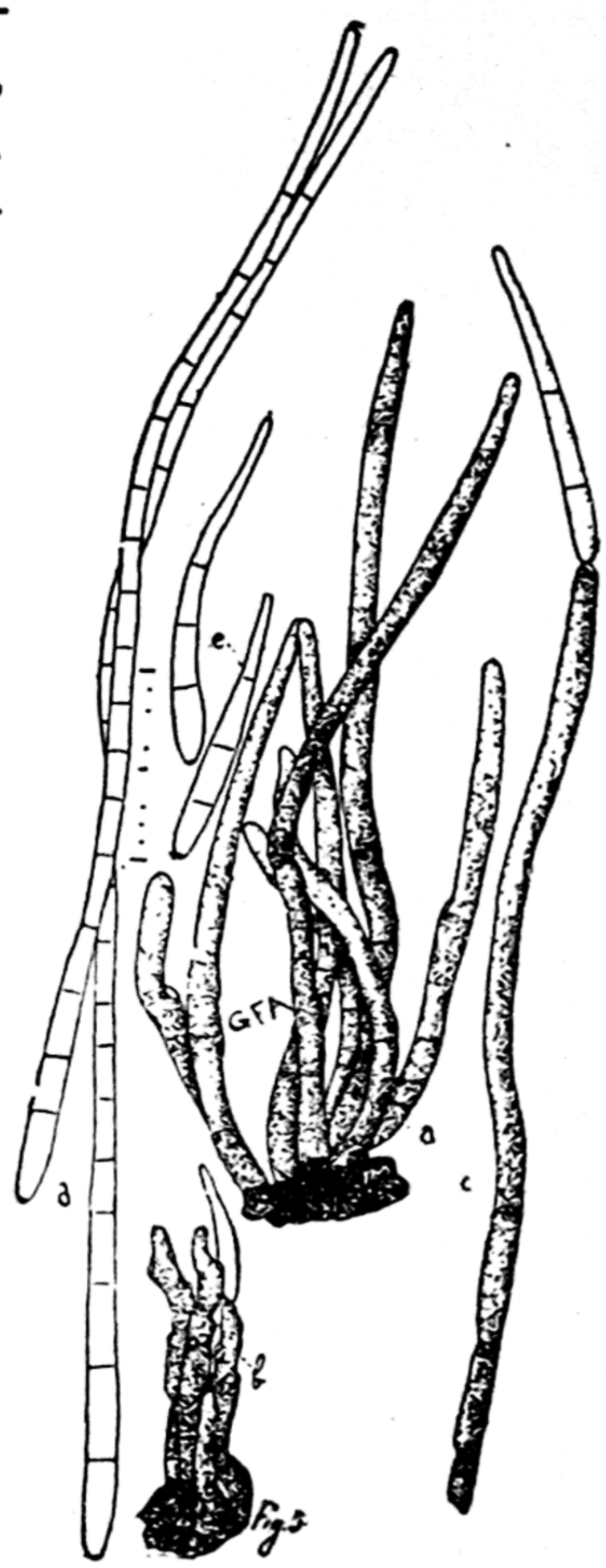


FIG. 426.—C. apii. After Duggar and Bailey.



FIG. 427.—Fertile hyphae and spores of C. beticola. After Duggar.

C. flagelliformis E. & H.

Spots amphigenous, indefinite, yellowish; conidia very long, curved, tapering.

The cause of spinach leaf spots.

C. citrullina Cke.

Epiphyllous, spots orbicular, 2–4 mm. in diameter, white with a purple margin; conidiophores elongate, terete, pale olivaceous, conidia very long, attenuate above, few-septate, hyaline, 120–140 x 3 μ.

The cause of leaf spots on watermelon.[353]

C. cucurbitæ E. & E.[14]

Spots amphigenous, rounded, subochraceous, becoming thin and white, 1 to 4 mm. in diameter, border slightly raised; conidiophores tufted, olive-brown, 70–80 x 4 μ, continuous, subgeniculate above, apically obtuse; conidia linear clavate, 100–120 x 3–4 μ, hyaline, septate.

On cucumbers in America, associated with Phyllosticta cucurbitacearum.

C. melonis Cke. grows on cucumbers and melons in England and New Zealand. What is probably the same fungus has been set up by Güssow [254] as a new genus **Corynespora.**

C. armoraciæ Sacc.

Spots amphigenous, pale; conidiophores short, simple, 30–40 x 5 μ; conidia rod-shaped, cuspidate, 100–120 x 5 μ, hyaline, multiseptate.

On horseradish.

C. bloxami B. & Br. occurs on Brassica.

C. personata (B. & C.) E.

Spots hypophyllous, small, brown, orbicular, 2–4 mm. or more in diameter; conidiophores densely tufted, short, brown, continuous; conidia clavate, pale-brown, about 3 to 4-septate, 30–50 x 5–6 μ.

On the peanut in the Southern United States and West Indies.[366]

C. cruenta Sacc.

Spots amphigenous, indefinite, reddish; conidiophores, subfasciculate, simple, subdenticulate, light olivaceous; conidia obclavate, curved, 60–80 x 4 μ, subacute, 6 to 7-septate, hyaline or olivaceous.

On cowpea and bean in America. Usually causing but slight damage.

C. vignæ Rac. (not E. & E.) is described as injurious to the cowpea in Java.[354]

C. medicaginis E. & E.

Spots amphigenous, smoky to black, 0.5–5 mm. in diameter, orbicular, indefinite; conidiophores subhyaline, becoming brownish, continuous, geniculate, 35–45 x 4–5 μ; conidia cylindric-fusoid, 3 to 6-septate, 40–60 x 3 μ.

On alfalfa and crimson clover.[355]

C. ariminensis Br. & Cav. is found on sulla leaves;

C. saccharii Br. d. H. **C. longipes** Butler, **C. acerosum** D. & H., **C. vaginæ** [61] and **C. kopkei** Krug. are on sugar-cane.

C. capparidis Sacc. is found on caper.

C. asparagi Sacc. & **C. caulicola** Wint. affect asparagus.

C. malkoffi Bubak causes an anise disease in Sadova.

C. theæ v. Br. d. H. occurs on tea in India;

C. violæ Sacc.

Spots amphigenous, rounded, bleached; conidiophores short, simple, greyish, 30–35 x 4 μ; conidia long and slender, rod-shaped, multiseptate, hyaline, 150–200 x 3.5 μ.

It produces a violet leaf spot.[26]

C. althæina Sacc. occurs on hollyhock.

Spots amphigenous, brown, 2–4 mm. broad; conidiophores fasciculate, slender, 40 x 5 μ, few-septate, olive brown; conidia apical, cylindric, to obclavate or broadly fusoid, straight, 40–60 x 5 μ, apically obtuse, 2 to 5-septate, hyaline.

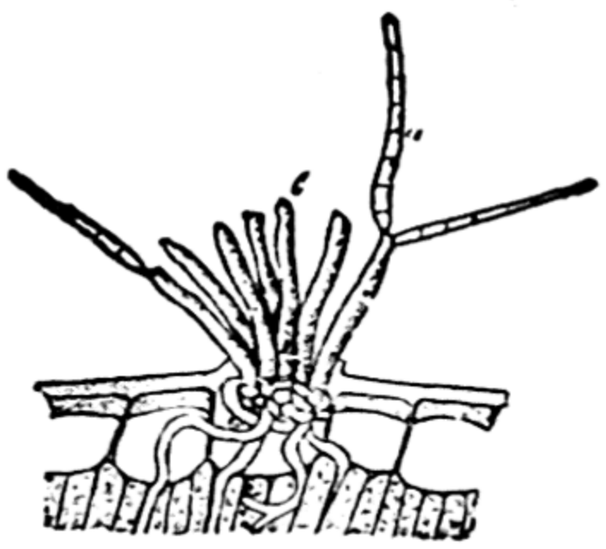


FIG. 428.—C. rosæcola. After Southworth.

C. kellermanii Bub.

Spots amphigenous, irregular, angular, olive-brown, up to 1 cm. across; conidiophores fasciculate, slender, few-septate, 150 μ x 4–5 μ, olive-brown; conidia filiform, 50–150 x 4–5 μ, 5 to 15-septate, straight or curved, hyaline.

It also occurs on hollyhock and is nearly related to C. malvarum Sacc.

C. rosicola Pass.[26]

Spots ochraceous, fuscous-margined, 2–3 mm. in diameter;

conidiophores cespitose, small, densely gregarious, fuliginous, subcontinuous, 20–40 x 3–5 μ, conidia cylindric, straight, short, 30–50 x 3.5–5 μ, subfuscous, 2 to 4–septate.

On roses.

C. hypophylla Cav. on roses in Europe is very like the preceding species.

C. omphacodes E. & H. and **C. phlogina** Peck. are the causes of rather unimportant leaf spots of cultivated phlox.

C. neriella Sacc. is on oleander.

C. sordida Sacc. produces leaf spots and defoliates Tecoma.

C. angreci Roum. is on orchids;

C. cheiranthi Sacc. on Cheiranthus.

C. brunkii E. & G. is reported on the geranium (Pelargonium zonale.)

C. resedæ Fcl.[356]

Spots punctiform, greyish; conidiophores fasciculate, simple, continuous or few-septate, 50–70 x 4–5 μ, fuscous; conidia apical to linear, obclavate, 4 to 5-septate, hyaline, 100–140 x 2.5–3 μ.

Spots are caused on the mignonette and the plants are blighted. The hyphæ appear through the stomata.

C. odontoglossi P. & D. occurs on cultivated Odontoglossum;

C. unicolor S. & P. on lily.

C. richardiæcola Atk.[21]

Spots amphigenous, black, with small white centers, subcircular, 2–6 mm. broad; conidiophores fasciculate, light-brown with a reddish tinge, becoming reddish-brown, erect or apically flexuose, denticulate, 30–80 x 5 μ; conidia hyaline, obclavate, 4 to 10 or more septate, 50–100 x 3–4 μ.

On calla lily.

C. microsora Sacc.[33]

Spots amphigenous, minute, brown, gregarious; conidiophores subfasciculate from a tubercular stroma, short, continuous, sub-olivaceous, 20–30 x 3 μ; conidia filiform, 3 to 5-septate, constricted at the septa, olivaceous, 35–45 x 3.5 μ.

It causes spotting and defoliation of Tilia.

C. cercidicola E.

Spots amphigenous, dull grey above, rusty-brown beneath, with a blackish-brown raised border; conidiophores amphigenous,

fasciculate, brown, 90–114 x 3.5–4 μ, subgeniculate above; conidia oblong, clavate, faintly 3-septate, 30–40 x 5–7 μ.

It seriously injures the Japanese red-bud and occurs also on the American species.[357]

C. acerina Hartig is on maple seedlings.

C. sequoiæ E. & E.

Large compact olivaceous tufts are formed on languid leaves; conidiophores ferruginous, brown, abruptly bent, subnodose, toothed, sparingly septate, 50–70 x 4–5 μ; conidia oblong, becoming clavate, 40–70 x 6 μ, concolorous with the hyphæ, 3 to 5-septate, constricted at the septa.

It is said to seriously interfere with the growth of Sequoia in the eastern states.

C. halstedii E. & E.

Spots hypophyllous, indefinite, brownish to olivaceous, 2–4 mm. across; conidiophores few-septate, 100–150 x 5–7 μ, undulate or crisped; conidia obclavate, 65–80 x 5–7 μ, 3-septate, somewhat constricted.

It produces blotches on pecan leaves and causes partial defoliation.[289]

Stilbaceæ (p. 565)

Sterile hyphæ creeping, scanty; fertile hyphæ collected into a stalk-like or stroma-like fascicle, bearing conidia at the top, more rarely along the sides, pale, bright-colored or dark.

Key to Sections of Stilbaceæ

Hyphæ and conidia hyaline or light colored	I. **Hyalostilbeæ.**
Conidia globose, elliptic or oblong	
1-celled	1. **Amerosporæ**, p. 633.
2-celled	2. **Didymosporæ.**
3 to several-celled	3. **Phragmosporæ.**
Conidia filiform, coiled	4. **Helicosporæ.**
Hyphæ or conidia dark	II. **Phæostilbeæ.**
Conidia globose, elliptic, or oblong,	
With cross walls only	
1-celled	5. **Amerosporæ**, p. 635.

2-celled	6. **Didymosporæ.**
3 or more-celled	7. **Phragmosporæ,** 637.
Muriform	8. **Dictyosporæ.**
Conidia of a stellately arranged group of cells	9. **Staurosporæ.**

Hyalostibeæ-Amerosporæ (p. 632)

Bright or light-colored, conidia globose, elliptic or oblong, continuous.

Key to Genera of Hyalostibeæ-Amerosporæ

Conidial part distinctly capitate or at least terminal	
Conidia not in chains	
Head of conidia not gaping or splitting above	
Head not spiny	
Conidiophores of head normal	
Conidia covered with mucus	
Synnema monocephalous	
Conidiophores dendroid-verticillate	
Without distinct sterigmata	1. **Dendrostilbella.**
With obpiriform sterigmata	2. **Pirobasidium.**
Conidiophores not dendroid-verticillate	3. **Stilbella,** p. 635.
Synnema polycephalous	
Capitula on extremely short branches	4. **Polycephalum.**
Capitula on spreading subulate branches	5. **Tilachlidium.**
Capitula on erect branches	6. **Corallodendron.**
Conidia without mucus	
Synnema monocephalous	
Conidiophores spirally twisted	7. **Martindalia.**

Conidiophores more or less straight
Conidia rhombic or biconic. . . . . 8. **Rhombostilbella**, p. 635
Conidia globose to fusoid . . . . . 9. **Ciliciopodium.**
Synnema polycephalous
Terrestrial, large, 1–2 cm.; conidia ovoid . . . . . 10. **Macrostilbum.**
Not terrestrial, small; conidia elongate-ovate.. 11. **Chondromyces.**
Conidiophores conidium-like, septate; monocephalous . . . . . 12. **Atractiella.**
Head spiny with radiating spicules
Spicules conic, granulate . . . . . 13. **Actiniceps.**
Spicules with many curved branches at middle . . . . . 14. **Heterocephalum.**
Head of conidia persistent below, splitting above. . . . . 15. **Pilacre.**
Conidia in chains
Synnema with conidia above; conidia without mucus
Synnema not pubescent. . . . . 16. **Coremium**, p. 635.
Synnema pubescent. . . . . 17. **Lasioderma.**
Synnema with conidia below; conidia with mucus. . . . . 18. **Microspatha.**
Conidial part cylindric or long-clavate
Conidia more or less equally scattered
Sterigmata denticulate, branched. . . . 19. **Cladosterigma.**
Sterigmata none or simple. . . . . 20. **Isaria**, p. 635.
Conidia in lateral heads or racemes
Conidia in racemes; synnema lobate . . . . . 21. **Peribotryum.**
Conidia in heads
Conidiophores with lateral nodes, usually escaping through the stomata. . . . . 22. **Helostroma.**
Conidiophores without nodes, usually entomophilous. . . . . 23. **Gibellula.**

Stilbella Lindau (p. 633)

Hyphæ forming a coremium which is capitate above; conidiophores borne on the cap; conidia small, often enclosed in slime.

Over one hundred species chiefly saprophytes. (Commonly known as Stilbum but the type of the genus being a hymenomycete it was renamed.)

S. flavida (Cke.) Kohl. causes a serious coffee disease.

S. theæ Bern. is on tea in India.

S. nanum Mas. causes the thread blight of tea.

S. populi on poplar = Mycosphærella populi. See p. 250.

Rhombostilbella Zimmermann (p. 634)

Synnemata verticillate-stilbiform; conidia rhomboid to biconic, acute, without mucus. Monotypic.

R. rosæ Zimm. is found on Liberian coffee.[359]

Coremium Link (p. 634)

Coremium cylindric, apically enlarged and fertile; conidia very small, catenulate. A small genus. In part = Rosellinia and Penicillium. See p. 230.



FIG. 429. — Coremium glaucum. After Corda.

Isaria Persoon (p. 634)

Stromata erect, clavate or branched, fertile throughout, hairy; conidia small, globose to ellipsoid, hyaline.

Over one hundred species, chiefly entomogenous.

I. fuciformis Berk. is reported from England and Australia forming its stromata on the inflorescences of Festuca.

I. graminiperda B. & M. also causes considerable injury to grasses in Australia.[360]

Phæostilbeæ-Amerosporæ (p. 632)

Dark conidia continuous, globose to elongate.

Key to Genera of **Phæostilbeæ-Amerosporæ**

Conidia not in chains
- Synnema setose. . . . . 1. **Saccardæa.**
- Synnema naked
  - Conidia asperate, on minute basidia. . . 2. **Basidiella.**
  - Conidia smooth
    - Synnema carnose, racemose-branched 3. **Stilbothamnium.**
    - Synnema fibrous or corneous, not racemose
      - Conidiophore lageniform. . . . . 4. **Ceratocladium.**
      - Conidiophore lacking, at least not lageniform
        - Synnema stalked, fibrous
          - Conidia dark, globose to elliptic. . . . . 5. **Sporocybe.**
          - Conidia hyaline
            - Conidia ovoid to oblong. . . 6. **Graphium.**
            - Conidia elongate or falcate. 7. **Harpographium.**
        - Synnema sessile, corneous. . . . . 8. **Glutinium.**

Conidia in chains
- Synnema setose. . . . . 9. **Trichurus.**
- Synnema not setose
  - Stalk branched above . . . . . 10. **Stemmaria.**
  - Stalk simple or nearly so
    - Capitule loose
      - Base of synnema subequal; usually on stems. . . . . 11. **Stysanus,** p. 636.
      - Base of synnema perithecioid; usually on leaves. . . . . 12. **Graphiothecium.**
    - Capitule compact
      - Conidia globose
        - Conidia echinulate. . . . . 13. **Harpocephalum.**
        - Conidia smooth
          - Conidia pleurogenous. . . . . 14. **Heydenia.**
          - Conidia acrogenous. . . . . 15. **Briosia.**
      - Conidia ovoid to oblong. . . . . 16. **Antromycopsis.**

Stysanus Corda

Stromata erect, cylindro-clavate, dark, rigid; conidia in an oblong

or subglobose panicle, ovoid, lemon-shaped or fusoid, subhyaline.

Some twenty-five species. See Fig. 430.

S. veronicæ Pers. occurs on cultivated Veronicas in Italy;

S. ulmariæ M'W. on Spirea in Ireland.

S. stemonitis Cda. causes a brown rot of potatoes in storage.

Phæostilbeæ-Phragmosporæ (p. 633)

Conidia 3 to several-celled, oblong to cylindric, dark or hyaline.

Key to Genera of Phæostilbeæ-Phragmosporæ

Conidia capitate	
Synnema simple	
Synnema black; conidia densely capitate.	1. **Arthrobotryum.**
Synnema fuscous or pale; conidia loosely capitate.	2. **Isariopsis,** p. 637.
Synnema dendroid-branched.	3. **Xylocladium.**
Conidia not capitate	
Conidia catenulate.	4. **Dendrographium.**
Conidia not catenulate	
Stalk fibrous	
Synnema simple or branched; conidia acro-pleurogenous.	5. **Podosporium.**
Synnema branched; conidia acrogenous.	6. **Negeriella.**
Stalk parenchyma-like	
Conidia pleurogenous, on a disk.	7. **Riccoa.**
Conidia acrogenous.	8. **Podosporiella.**

Isariopsis Fries

Slender, dark or subhyaline, cylindric hyphæ laxly aggregated; conidia in a lax panicle or head, cylindric or clavate. See Fig. 431.

I. griseola Sacc.

Spots hypophyllous, ochraceous; coremium stipitate, dense. 200 x 30–40 μ, composed of filiform hyphæ; conidia borne on the reflexed ends of the hyphæ, cylindric-fusoid, curved, 50-60 x 7–8 μ, grey, 1 to 3-septate, constricted.

It causes disease of beans.

Tuberculariaceæ (p. 565)

Hyphæ compacted into a globose, discoid, or verruciform body,



FIG. 430.—Stysanus.
After Saccardo.



FIG. 431.—Isariopsis.
After Saccardo.

the sporodochium; sporodochia typically sessile, waxy or subgelatinous, white, bright-colored or dark to black.

In part = Nectria, Claviceps and Hymenoscypha, etc. See pp. 146, 201, 211.

KEY TO SECTIONS OF Tuberculariaceæ

Hyphæ and conidia hyaline or bright-colored	I. **Mucedineæ.**
Conidia globose to fusoid or falcate	
Conidia continuous.	1. **Amerosporeæ,** p. 639.
Conidia 1-septate.	2. **Didymosporæ.**
Conidia 2 to many-septate.	3. **Phragmosporæ,** p. 645.
Conidia muriform.	4. **Dictyosporæ.**
Conidia spirally coiled.	5. **Helicosporæ.**
Conidia forked or cruciate.	6. **Staurosporæ.**
Hyphæ olive to brown or black; conidia concolorous, rarely hyaline	II. **Dematieæ.**
Conidia globose to elongate	
Conidia continuous.	7. **Amerosporæ,** p. 654.
Conidia 1-septate.	8. **Didymosporæ.**

Conidia 2 to many-septate.	9. **Phragmosporæ**, p. 657.
Conidia muriform.	10. **Dictyosporæ**, p. 658.
Conidia filiform, hyaline.	11. **Scolecosporæ.**
Conidia spirally twisted.	12. **Helicosporæ.**
Conidia angulose-stellate.	13. **Staurosporæ.**

Tuberculariaceæ-Mucedineæ-Amerosporæ (p. 638)

Conidia hyaline, or bright-colored, continuous, globose to fusoid; hyphæ hyaline.

Key to Genera of Tuberculariaceæ-Mucedineæ-Amerosporeæ

Sporodochia smooth or nearly so	
Conidiophores normal	
Conidia muticate	
Conidia not covered with mucus	
Conidia not acrogenous-capitate	
Sporodochium girt by a heterogenous cup.	1. **Patellina.**
Sporodochium without a heterogenous cup	
Conidia not catenulate or scarcely so	
Conidia escaping from interior of hyphæ	
Conidiophores branched.	2. **Endoconidium**, p. 641.
Conidiophores simple.	3. **Trichotheca.**
Conidia arising on outside of hyphæ	
Conidiophores lacking	
Conidia large, pellucid	
Conidia globose.	4. **Sphærosporium.**
Conidia oval.	5. **Diaphanium.**
Conidia small, not pellucid.	6. **Pactilia.**
Conidiophores present	
Conidia pleurogenous or acro-pleurogenous	
Conidia globose.	7. **Beniowskia.**
Conidia ovoid to oblong.	8. **Tubercularia**, p. 642.
Conidia fusoid to cylindric. . . .	9. **Fusicolla.**
Conidia acrogenous	

Conidiophores verrucose. . . . . 10. **Dacrymycella.**
Conidiophores not verrucose
Uredinicolous. . . . . 11. **Tuberculina.**
Not uredinicolous
Sporodochia globose
Conidia giobose; conidiophores short. . . . . 12. **Ægerita.**
Conidia ovoid; conidiophores branched. . . . . 13. **Granularia.**
Sporodochia pulvinate
Conidia acicular. . . . . 14. **Kmetia.**
Conidia terete-oblong. . . . . 15. **Bactridiopsis.**
Sporodochia disk-shaped. . . . . 16. **Hymenula.**
Sporodochia cupulate. . . . . 17. **Hyphostereum.**
Sporodochia verruciform or effuse
Conidiophores simple
Conidiophores radiate, united at base
Conidiophores not arising from a cellular mass.. 18. **Clinoconidium.**
Conidiophores arising from a cellular mass. . . . . 19. **Ustilaginoidea,** p. 643.
Conidiophores not united or radiate. . . . . 20. **Sphacelia,** p. 643.
Conidiophores dendroid branched. . . . . 21. **Dendrodochium,** p. 643.
Conidia in chains
Conidia covered with mucus. . . . 22. **Collodochium.**
Conidia without mucus
Conidia globose
Conidia hyaline. . . . . 23. **Sphærocolla.**
Conidia blue. . . . . 24. **Sporoderma.**
Conidia elliptic to oblong
Sporodochium disk-shaped, orange-red . . . . . 25. **Necator,** p. 643.
Sporodochium subglobose, whitish. . . . . 26. **Patouillardia.**
Conidia cylindric
Sporodochium dilated above, stalked. . . . . 27. **Bizzozeriella.**

Sporodochia globose to verruciform
Sporodochia gelatinous, sessile — 28. **Cylindrocolla.**
Sporodochia not gelatinous, short-stalked — 29. **Sphæridium.**
Conidia acrogenous-capitate; sporodochia turbinate — 30. **Cephalodochium.**
Conidia covered with mucus
Sporodochium globose, hardened — 31. **Thecospora.**
Sporodochia verruciform or subeffuse — 32. **Illosporium,** p. 643.
Sporodochia discoid — 33. **Epidochiopsis.**
Conidia ciliate
Conidia 1-ciliate at base only — 34. **Stigmatella.**
Conidia 1-ciliate at each end — 35. **Thozetia.**
Conidia 7 to 8-ciliate at each end — 36. **Chætospermum.**
Conidiophores with internal conidia-bearing areoles — 37. **Scoriomyces.**
Sporodochia setulose, ciliate or uniformly woolly
Sporodochia woolly or setulose
Sporodochia setulose; conidia catenulate — 38. **Periola.**
Sporodochia woolly or velvety; conidia capitate
Conidia globose — 39. **Dacryodochium.**
Conidia oblong — 40. **Lachnodochium.**
Sporodochia ciliate at the margin
Sporophores none; conidia coacervate — 41. **Volutellaria.**
Sporophores distinct
Conidia in chains — 42. **Volutina.**
Conidia not in chains
Conidiophores 6-ciliate above, united below — 43. **Guelichia.**
Conidiophores not ciliate or united — 44. **Volutella,** p. 644.

Endoconidium Prillieux & Delacroix (p. 639)

Sporodochia pulvinate, white; conidiophores hyaline, racemose; conidia hyaline, rounded, formed within the conidiophore and escaping apically.

A small genus, chiefly saprophytes.

E. temulentum P. & D. = **Hymenoscypha temulenta.** See p. 146.

Tuberculariaceæ Tode (p. 639)

Sporodochium tubercular or wart-like, sessile or subsessile, smooth, rarely with bristles, usually reddish; conidiophores very slender, usually branched; conidia apical, ovate to elongate. In part = Nectria. See p. 201.



FIG. 432.—Hyphæ of Tubercularia, bearing conidia. After Durand.

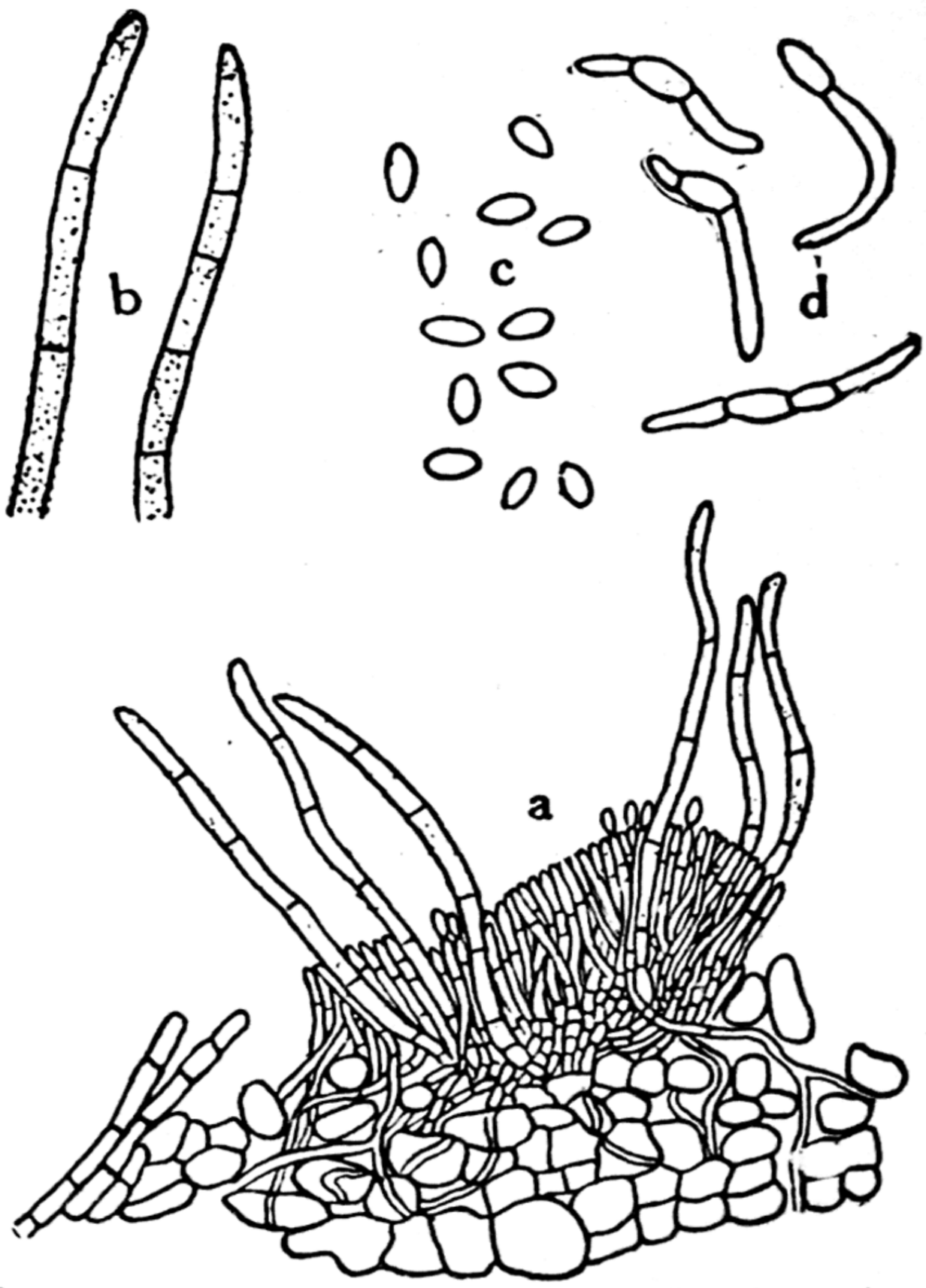


FIG. 433.—T. fici, sporodochium, showing setæ and conidial formation. After Edgerton.

Over one hundred species, chiefly saprophytes.

T. vulgaris Tode = Nectria cinnabarina. See p. 202.

T. fici Edg.[74, 361]

Sporodochia scattered or gregarious, superficial or subcuticular, light pink, variable in size up to 3–4 x 1–1.5 mm., smooth, irregular in outline; conidiophores crowded, hyaline, 20–27 x 1–2 μ; conidia small, clear, elliptic to oval, regular in size, 5–7 x 2.5–5 μ;

setæ scattered or abundant, variously placed, straight or curved, hyaline or subhyaline, septate, papillose, 60–90 x 4–6 μ.

It is the cause of a fig canker.

Tuberculina Saccardo

Several species occur in sori of the Uredinales.

Ustilaginoidea Brefeld, a small genus of Ascomycetes, one species of which, U. virens, on rice is known only in the conidial stage. See p. 214.

Sphacelia Léviellé (p. 640)

Sporodochia planose, effuse, stromate or sclerotioid; conidiophores short, simple, filiform; conidia apical, ovate.

A small genus, chiefly conidia of Claviceps and related genera.

S. segetum Lév. =Claviceps purpurea. See p. 212.

S. typhina (Pers.) Sacc. =Epichloe typhina. See p. 210.

Dendrodochium Bonardin (p. 640)

Sporodochium pulvinate or verruciform, white or light-colored; conidiophores verticillate, branched; conidia acrogenous, ovoid to oblong.

A genus of about forty species.

D. lycopersici March is found on tomatoes in Belgium.[362]

Necator Massee (p. 640)

Sporodochium erumpent, small, slightly convex, becoming orange-red; conidia oblong or elliptic, catenulate, contents orange. Monotypic.

N. decretus Mas. is a dangerous parasite of coffee, tea, etc.[363, 364]

Illosporium Martius (p. 641)

Sporodochia wart-like, pulvinate or subeffuse, white or light-colored, subgelatinous or waxy; conidiophores variable; conidia globose, sigmoid, variable, embedded in mucous. There are some forty species.

I. malifoliorum Shel.

Spots suborbicular or coalescing and becoming irregular, brown

or mottled with gray and with a small gray spot near the center, 5–15 mm. in diameter; sporodochia hypophyllous, minute, gelatinous, yellow-amber, becoming black, spherical, becoming discoid or irregular, 150–160 μ in diameter; conidiophores branched; conidia oblong, 1–3.5 x 4 μ.



FIG. 434.—Illosporium maculicola. After Saccardo.

It is said by Sheldon [365] to be one of the most common and destructive causes of leaf spots of the apple often resulting in nearly complete defoliation. In the centers of the leaf spots other spots bearing other species of fungi are often found, leading to the thought that perhaps the Illosporium in such cases results from secondary infection in the wounds made by the earlier fungus. The sporodochia are hypophyllous, often hidden by the normal pubescence of the leaf.

Volutella Tode (p. 641)

Sporodochia discoid, regular, margin ciliate, sessile or stipitate; conidiophores usually simple; conidia ovoid to oblong.

Some seventy species.

V. leucotricha Atk.

Sporodochia convex-discoid, white to pale flesh-color; setæ few, filiform, few-septate, subhyaline; conidiophores densely fasciculate, filiform; conidia oblong.

On cuttings in greenhouses.

V. fructi S. & H.

Spots on the fruit, circular; sporodochia, numerous in concentric circles, subcuticular, erumpent, elevated 200–250 μ, 150–400 μ in diameter; mycelium black; setæ distributed throughout the sporodochium, black, 0 to 3-septate, acute, smooth, 100–400 x 5–8 μ; conidiophores elongate, hyaline, simple, 25–35 x 3 μ; conidia smooth, oblong-fusoid to falcate-fusoid, hyaline or sub-olivaceous, 17–23 x 2.5–3.5 μ.

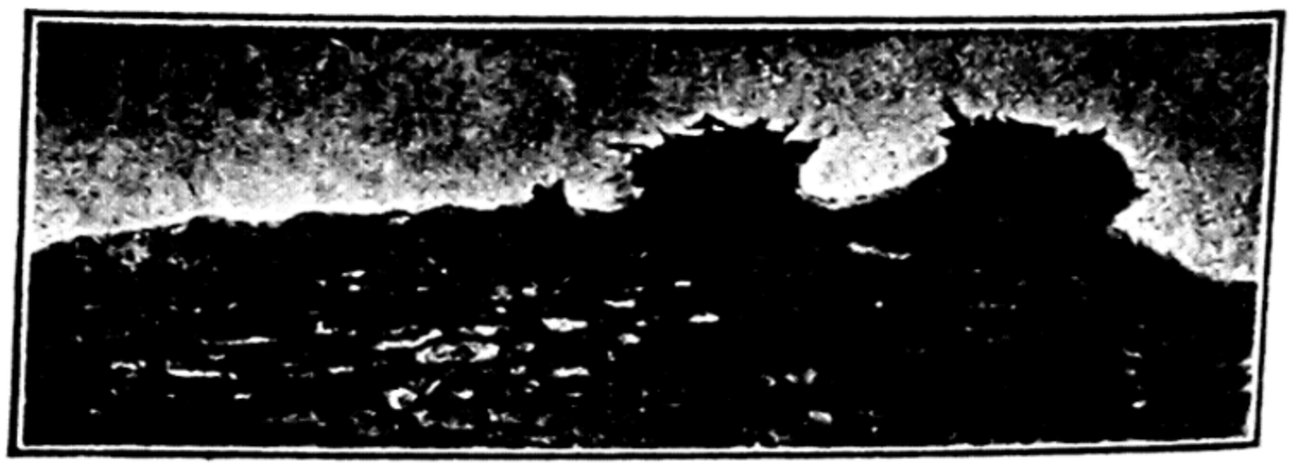


FIG. 435.—V. fructi. Sporodochia in section. After Stevens and Hall.

It is the cause of a dry rot of apples.[88, 367]

V. dianthi (Hal.) Atk.[21]

It is the cause of anthracnose of carnation.

The acervuli are conspicuous with black setæ.

V. concentrica Hals. is reported by Halsted as the cause of leaf spots of Bletia.[21]

Tuberculariaceæ-Mucedineæ-Phragmosporæ (p. 638)

Hyphæ hyaline; conidia 2 to several-septate, hyaline or bright-colored, fusoid to falcate, rarely short and simple in some species of Fusarium.

Key to Genera of Tuberculariaceæ-Mucedineæ-Phragmosporæ

Conidia somewhat catenulate, cylindric. . . .	1. **Discocolla.**
Conidia rarely catenulate	
Conidia cruciately 4-celled; sporodochium gelatinous.	2. **Sarcinodochium.**
Conidia not cruciate	
Conidiophores short, simple	
Conidia very large, terete-oblong. . .	3. **Bactridium.**
Conidia doliform.	4. **Pithomyces.**
Conidiophores more or less branched	
Conidiophores dichotomous; conidia key-like.	5. **Heliscus.**
Conidiophores usually verticillately branched, conidia usually falcate, sometimes oblong	
Sporodochium gelatinous.	6. **Pionnotes,** p. 645.
Sporodochium waxy or byssoid. . .	7. **Fusarium,** p. 646.

Pionnotes Fries

Sporodochium gelatinous, then firm, orange, pulvinate or lobed; conidiophores fasciculate, simple or branched; conidia rather large, fusoid to cylindric, curved.

Only twelve or fifteen species, chiefly saprophytes.

P. betæ Mas. occurs on mangels and beets and according to Massee is probably identical with **P. rhizophila** which attacks stored Dahlia roots and potatoes.

Fusarium Link (p. 645)

Sporodochium pulvinate, or subeffused; conidiophores branched; conidia terminal, solitary, fusiform or falcate, more or less curved, pluriseptate.

In part=Nectria, Neocosmospora, Gibberella. See pp. 201, 205, 206.

This is a large genus, (some four hundred species have been described) though future study will undoubtedly relegate many names to synonymy.

Many of the species are destructive parasites, invading the ducts of plants and by stoppage of the water-supply causing the class of diseases known as "wilts." Others induce rot, spotting, cankers, etc. Taken as a whole the genus is one of the most injurious with which plant pathology has to do.

It seems probable that some of the forms that live normally as saprophytes in soil may encroach upon living roots of susceptible plants when these are available.

In nature the spores typical of this form-genus are borne in sporodochia, coremia or acervuli and are crescent-shaped or fusoid. The same mycelium that produces these structures often, indeed usually, produces also similar and smaller conidia scattered on single hyphæ (=Cephalosporium). These two forms are called macroconidia and microconidia respectively. The microconidia are regarded by Appel & Wollenweber [368] as depauperate macroconidia. Frequently chlamydospores form in the mycelium; either terminal or intercalary. Sclerotia are also not uncommon.

Undoubted species of Fusarium have been shown to belong to several different Hypocrealous ascomycetes, while still more have as yet revealed no ascomycete connection.

Biologic specialization has been found, in that forms morphologically indistinguishable are frequently incapable of cross inoculation onto other than their usual hosts.

Fusarium grows well in culture and the species often show marked differences in growth on various media, particularly in the colors that are developed.

As with the anthracnoses much study is here needed to throw

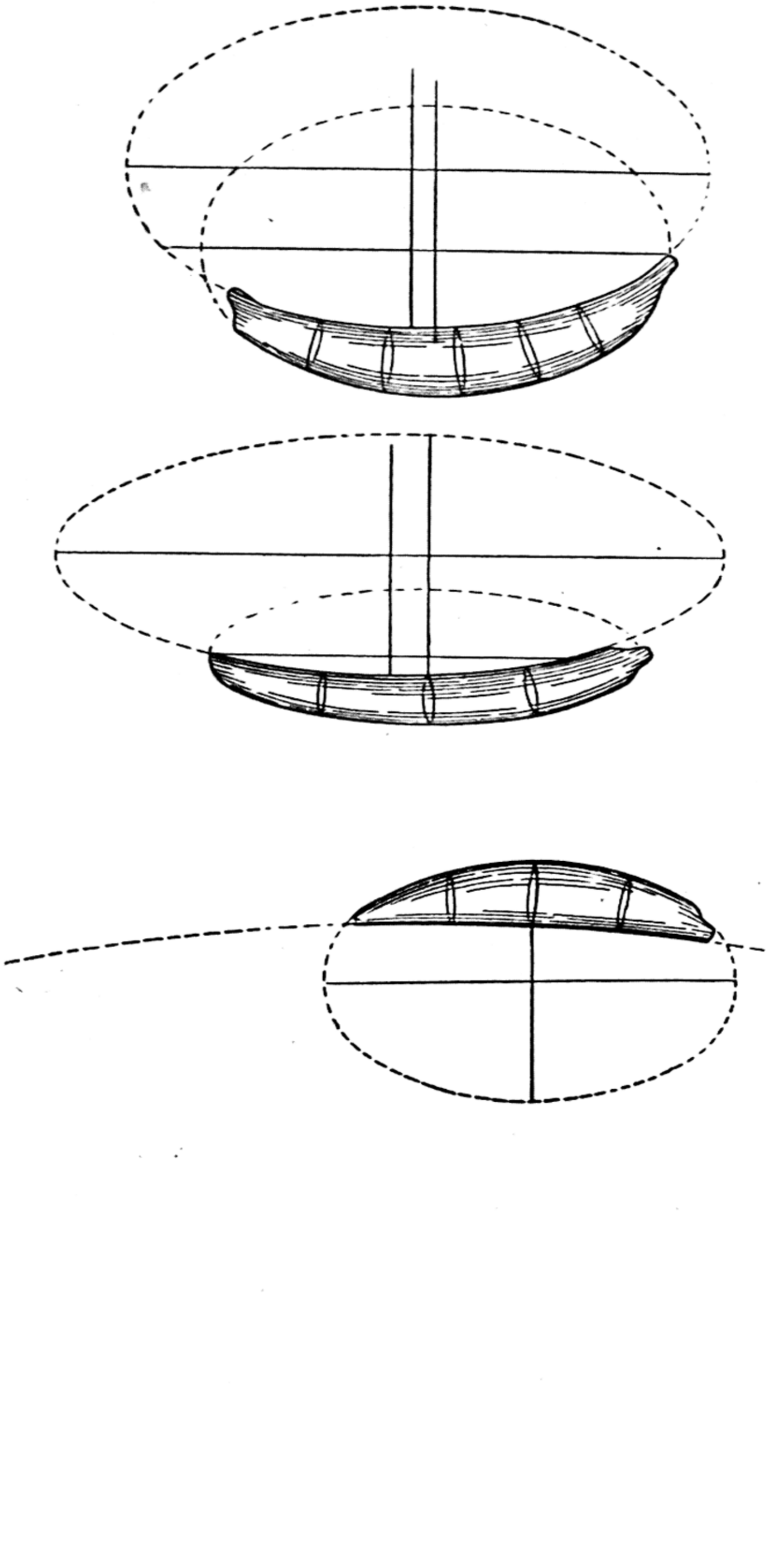


FIG. 436.—Spores of Fusarium showing curvature in different species. F. rubiginosum F. didymium, F. cæruleum. After Appel and Wollenweber.

light on the inter-relation of the various species and their hosts. Apple & Wollenweber [368] have made an extensive study of several species to lay the ground for a monograph. They conclude that in delimiting species important characters are the forms of the conidia, especially their bases, apices, and degree of curvature and septation (see Fig. 436); the color of the mycelium and spores; the presence or absence of chlamydospores. They cast aside as valueless many earlier descriptions substituting new diagnoses and new names. According to their conception, the following names should stand.

F. solani (Mart.) Sacc. =Fusisporium solani Mart. =Fusarium commutatum Sacc.

F. martii A. & W. =Fusisporium solani Mart.

F. cœruleum Lib. =Fusarium solani.

F. discolor A. & W. =Fusarium solani.

F. rubiginosum A. & W. =Fusarium solani.

F. discolor var. **sulphureum** (Schl.) A. & W. =Fusarium sulphureum Schlecht.

F. subulatum A. & W.

F. metachroum A. & W.

F. orthoceras A. & W. =F. oxysporum Sm. & Sw. not Schl.

F. theobromæ A. & Struk.

F. wilkommii Lin. =F. bacilligerum B. & Br.

F. falcatum A. & W. =F. vasinfectum pisi Schk.

F. gibbosum A. & W.

It will be noted that several of the species mentioned below are here involved.

F. platani Mont. =Calonectria pyrochroa. See p. 205.

F. rubi Wint.

Mycelium white, becoming pink, especially abundant on the flowers; conidia elongate, 1 to 8–septate, variable in size and form, straight or curved, 14–30 x 3–3.5 μ, not constricted.



FIG. 437. — Section of ovary showing mycelium between carpel and ovule. After Cook.

Cook [369, 373] found this fungus in diseased buds of dewberries and by inoculation demonstrated that it is responsible for witches-broom, double-blossom, and similar abnormal growths of this plant.

F. gemmiperda Aderh. is described by Aderhold [370] as fatal to flower buds of cherry before they open, a conclusion supported by inoculation experiments. The disease in general appearance resembles sclerotiniose.

F. rhizogenum P. & C.

Sporodochia superficial, 1 to 2 mm. wide, dense, convex, white or whitish, hyphæ densely interwoven, septate, subramose; conidia oblong, roundish, 1-septate, 70 x 4 μ.

It was originally described as a parasite on apple roots in Nebraska [372] and is mentioned by Aderhold [30] as the cause of death of roots of apple and cherry trees in Europe. The mycelium grows within the roots and gummosis of the wood occurs. A Cephalosporium form is known, also chlamydospores.

F. putrefaciens Osterw.[374,375] is said by Osterwalder [374] to cause decay of pomaceous fruits.

F. cubense E. F. Sm. was isolated from bananas affected with blight. Inoculation showed the fungus capable of growing through the bundles for long distances.[376]

F. limonis Bri.[170, 377, 437]

Sporodochia gregarious, confluent, white; hyphæ spreading, branched, septate; conidiophores erect, with alternate or opposite branches; conidia variable, acrogenous, continuous to 3-septate, oblong to fusiform, curved, pointed, slightly constricted, 26–27 x 2.4–2.8 μ.

This fungus is held to be contributory to, if not responsible for, the Mal-di-gomma or foot-rot of citrous fruits which is known practically wherever these fruits are cultivated.

F. culmorum (W. Sm.) Sacc.[384, 385]

Reddish-yellow, gelatinous, effuse; hyphæ few-septate, tortuous; fertile, short, continuous; conidia fusoid-falcate, 3 to 5-septate, 28–32 x 6–8 μ on wheat.



FIG. 438.—F. culmorum. After Chester.

The fungus affects chaff and seed, first appearing as a whitening of the upper halves of the glumes followed later by a pink color. The glumes become cemented together and the whole head may be involved. The grains are of light weight and are often covered with the fungus. Chester

showed that the mycelium penetrates the seed and may even consume it entirely.

F. sp. occurs on raspberry.[378]

F. moniliforme Shel.

Sporodochium subeffuse, salmon-pink; conidiophores simple or with opposite branches; microconidia continuous, oblong-ovoid,

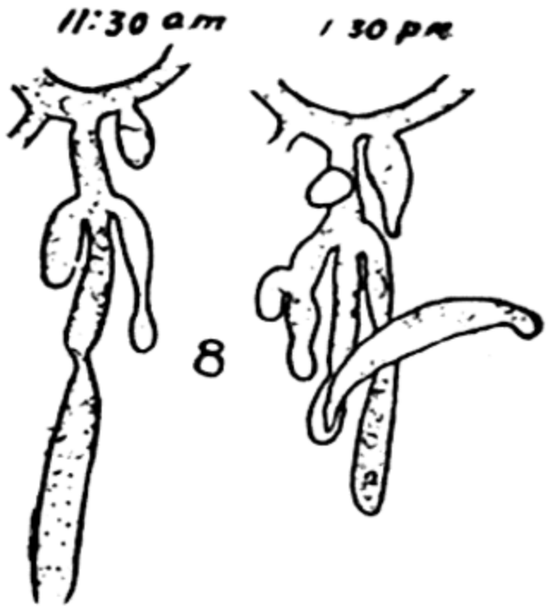


FIG. 439.—Fusarium on corn. After Burrill and Barrett.

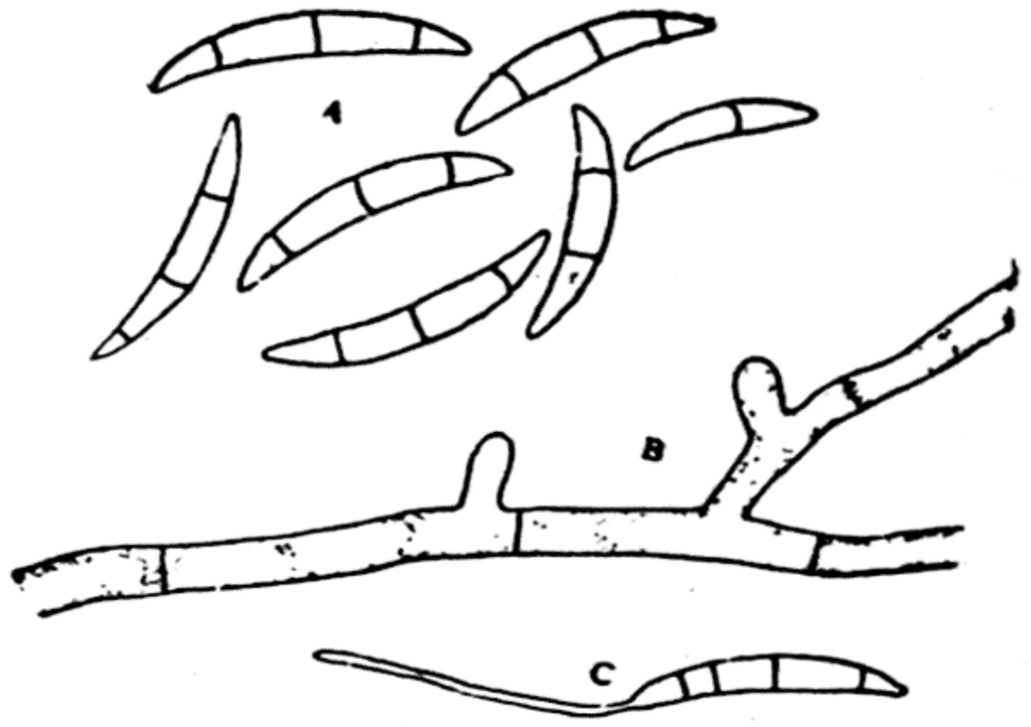


FIG. 440.—F. vasinfectum. A. Macroconidia. B. Portion of a hypha. C. A germinating macroconidium. After Reed.

moniliform, 6–10 μ long; macroconidia falcate, acute, usually 3-septate, 25–40 μ long.

It causes molding of corn.[379]

Several other undetermined species have been isolated from corn on which they occur as the cause of dry rot of the grain.[103]

A fusarium on banana is by Essed referred to Ustilaginoidella. See p. 214.

F. vasinfectum Atk.[380-383]

Hyphæ at maturity yellowish, 2–4 μ in diameter; conidia borne singly; microconidia oval, continuous; macroconidia falcate, 2 to 3-septate, 1–2 x 2–4 μ.

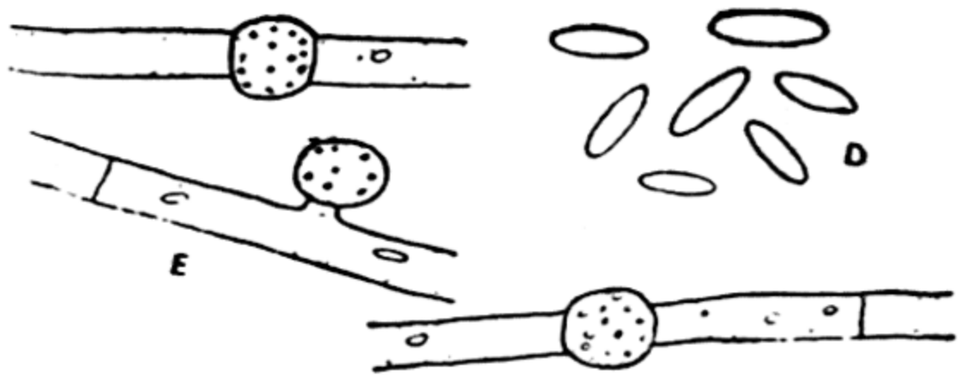


FIG. 441.—F. vasinfectum. D. Microconidia. E. Chlamydospores. After Reed.

Atkinson[381] first described this on cotton and okra in which plants it was found plugging the ducts with its mycelium. The mycelium here was 2–4 μ in diameter and microconidia were seen within the ducts. Pure cultures were obtained and inoculations with these on plants already injured by Pythium resulted in

infection. The ascigerous stage was said by Smith [380] to be a Neocosmospora and the many wilts caused by Fusarium have by various authors who follow Smith been reported as Neocosmospora though without real evidence that they are such. See page 205.

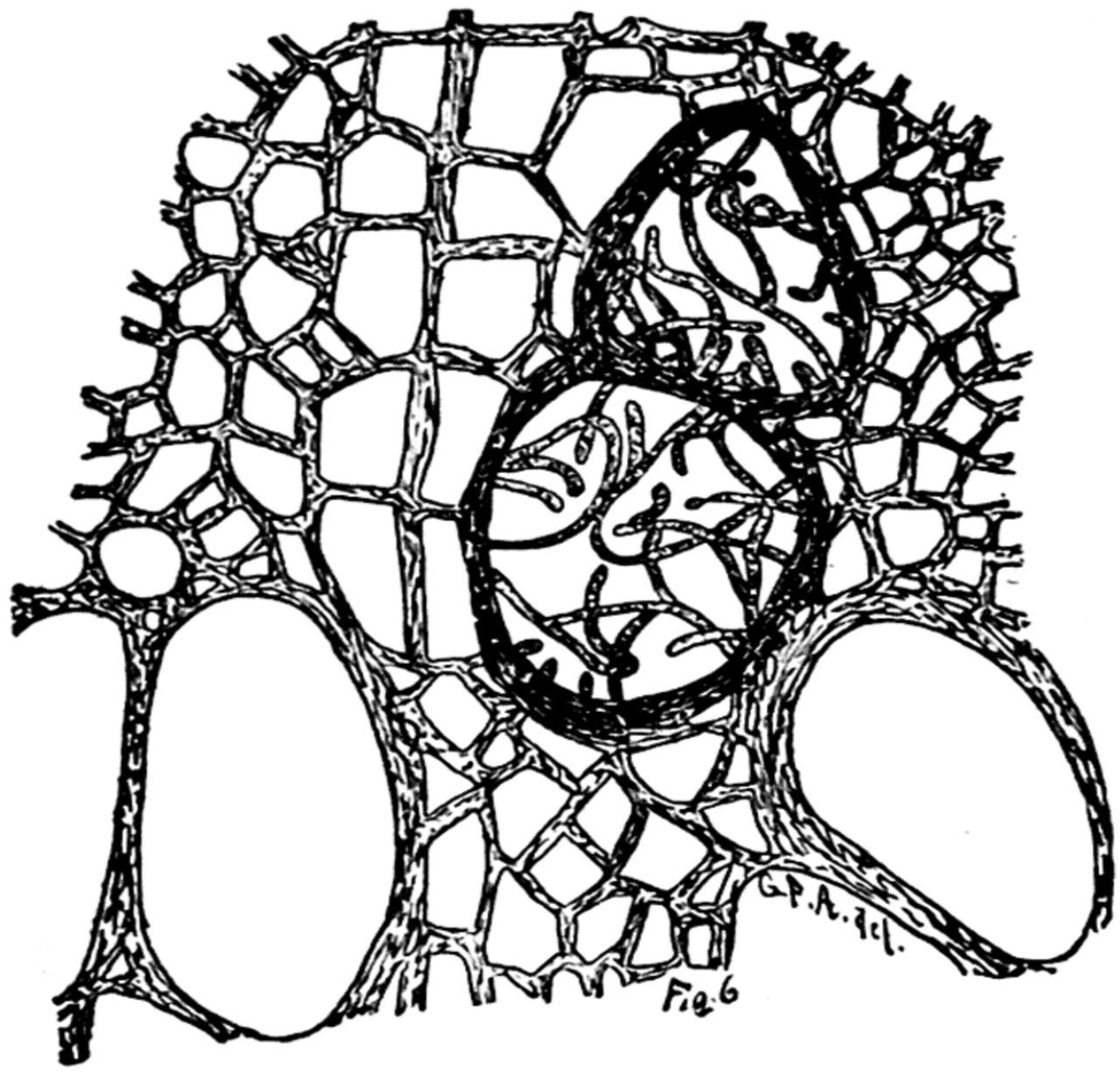


FIG. 442.—F. vasinfectum, showing thrombosis of veins. After Atkinson.

Recent studies of Higgins [383] and Butler [388] indicate that the Fusarium of the Neocosmospora is a saprophyte and that the Fusariums parasitic in the wilt diseases are as yet unknown in ascigerous form.

The Fusarium parasitic on cotton is believed to be identical with that on okra but distinct biologically if not morphologically from that of watermelon.

F. vasinfectum var. **tracheiphila** E. F. Sm.[389]

This form on cowpea, which appears to be morphologically identical with F. vasinfectum is not capable of infecting cotton.

F. niveum E. F. Sm.[390, 392-394] is the cause of the watermelon wilt. Morphologically it is like F. vasinfectum.

A fungus regarded by Reed [64, 393] as identical with this was also described as causing wilt of ginseng.

F. vasinfectum var. **pisi** v. Hall has been described as a variety affecting the pea.[386, 387]

F. udum Butler on pigeon pea in India is closely related to this last fungus.

F. aurantiacum (Lk.) Sacc. is recorded for cucurbs occurring on stems, leaves and fruits.

F. oxysporum Schl.[395, 396]

Sporodochia convex, subverrucose, rose, erumpent, confluent·

conidia on short conidiophores; microconidia continuous, elliptic; macroconidia falcate-fusoid, 3 to 4-septate, 40–60 x 7–8 μ.

Smith and Swingle [396] mention 11 described species of Fusarium recorded by Saccardo for the Irish potato, viz.;

Fusarium oxysporum Schl., F. (Fusisporium) solani (Mart.) Sacc., F. (Fusisporium) solani-tuberosa Mart., F. didymum Harting, F. solani Schl., F. (Fusisporium) roseolum (B. &. B.) Sacc., F. violaceum Fcl., F. cæruleum (Lib.) Sacc., F. diplosporum C. & E., F. commutatum Sacc., F. pestis Sorauer, F. æruginosum Delacroix, F. acuminatum E. & E., F. affine Fautr. & Lamb, all of which they tentatively regard as synonyms, attributing such differences as have been noted in descriptions to variations in the environment under which the fungus was growing when described. The potato disease caused is common over a considerable portion of the United States and is variously known as "bundle blackening," "stem rot," "dry end rot," and "dry rot."

The fungus grows readily on many culture media, showing large variation with the environment. It is aërobic and tolerates large amounts of malic, citric and tartaric acids.

F. acuminatum E. & E. Sporodochia gregarious, minute, whitish or flesh-colored; conidia falcate, attenate, 3 to 5 or 6-septate, not constricted.

Described by Stewart [397] as causing a girdling of potato stems in New York.

F. roseum-lupini-alba Sacc.

Sporodochia pulvinate, minute, confluent, cinnabarine; conidiophores variable, long, slender, branched, branches nodulose, fusoid; conidia fusoid falcate, 45–55 x 4 μ, 4 to 6-septate. It causes spots on leaves and pods of lupines and attacks the seeds, inducing rot.

F. cucurbitariæ Sacc. is on cucumbers in Queensland.

F. solani (Mart.) Sacc.

Sporodochia globose, irregular, white; conidiophores branched; conidia fusoid-falcate, 3 to 5-septate, 40–60 x 7–8 μ, subhyaline.

Clinton,[399] also Wehmer [398] and others, have shown this to be the cause of "dry end rot" of stored potatoes. It may be identical with F. oxysporum.

F. pestis Sor. is given by Sorauer as the cause of "black-leg"

(see p. 46) of potatoes; it is perhaps identical with **F. oxysporum.**

F. erubescens A. & v. Ov. produces small black sunken spots on gree ·ad ripe tomatoes in Germany[400] resulting finally in mummification. Parasitism by means of enzymes was demonstrated.

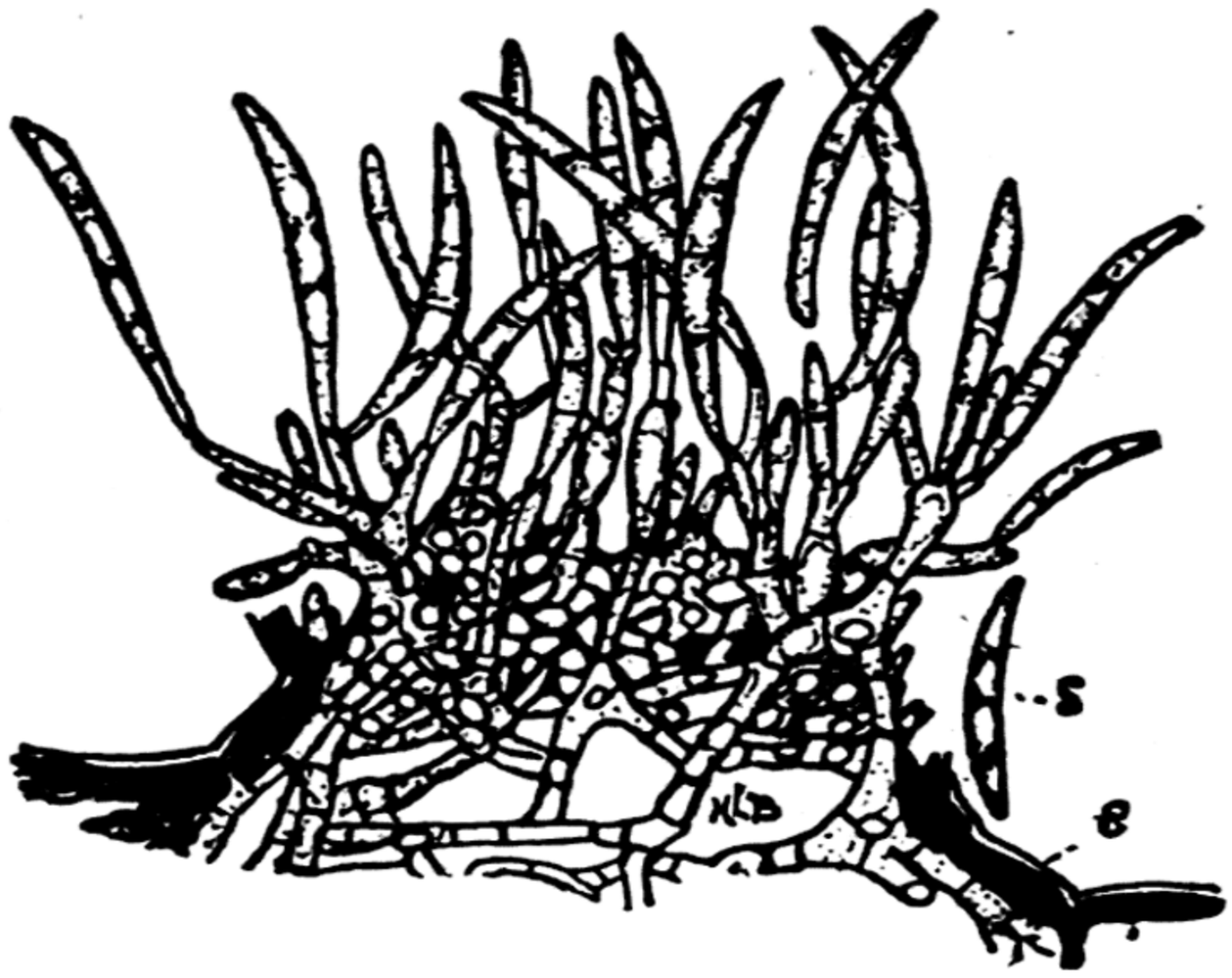


FIG. 443.—F. lini. After Bolley.

F. lycopersici Sacc.[401-402]

Sporodochia as in F. oxysporum; conidia falcate, acute, 25–30 x 3.5–4 μ, hyaline to yellowish.

It is the cause of a tomato wilt or "sleeping disease" resulting from vasion of the ducts. Conidia of two kinds are produced, Fusarium and Diplocladium. Infection is subterranean.

A nearly related disease differing chiefly in the fact that the fungus does not reach far above ground has been described by Smith.[402] The fungus in both cases is perhaps identical with F. oxysporum.



FIG. 444.—F. lini, sketch, showing the mode of attack upon a young root tip of a seedling flax plant. After Bolley.

F. lini Boll.[403]

Sporodochia erumpent, compact, cream to flesh-colored; conidiophores short, much-branched; conidia 3-septate, fusiform, slightly curved to falcate, 27–38 x 3–3.5 μ.

A serious widespread flax wilt is caused. The mycelium develops luxuriantly from bits of diseased stem laid in sterile Petri dishes and grows well in culture media. Normally a soil saprophyte, it invades the roots, grows through the veins, plugs the ducts and causes death. The sporodochia are found abundantly on the bases

of diseased plants. The spores abound on all diseased parts, particularly on the seeds. Infection experiments have demonstrated its pathogenicity.

F. tabacivorum Del. is said to cause a rot of tobacco in France.

F. brassicæ Thüm. is of economic importance on cabbage.[404]

Inoculations of an undetermined species of Fusarium in pure culture into soil also resulted in infection of 83% of the cabbage plants grown therein.

F. decemcellulare Brick and **F. theobromæ** Lutz. occur on cacao.

F. ricini (Ber.) Bizz. is injurious to the castor oil plant.

F. incarnatum (Desm.) Sacc. is reported as the probable cause of an aster wilt or blight in Europe.[405] An undetermined species is also reported on China aster by Galloway [406, 407] and others.

A species of Fusarium on carnation leaves following in rust sori was reported by Stewart [408] and a wilt disease or stem rot of carnation was studied by Sturgis.[409] He found the Fusarium in the affected plants, it was isolated and inoculated into the soil around the roots of carnations producing disease in several instances.

F. pelargonii Crou. is described from geraniums.[410]

F. dianthi P. & D.[411] on Dianthus cuttings, is a wound parasite, following insect injury.

F. violæ Wolf.

Infected areas dark, sunken; sporodochia within the host; conidia fusiform-falcate, 28–38 x 4–6 μ, 3 to 5 times septate; hyphæ hyaline, 4–7 μ in diameter, irregularly branched. It causes a disease of roots and stems of pansy

F. pini is believed to be the species responsible for a disease of pine seedlings.[412]

F. blasticola Rost. causes death of conifer seedlings in Europe.

Tuberculariaceæ-Dematiæ-Amerosporæ (p. 638)

Hyphæ olive to brown or black; conidia continuous, rarely hyaline globose to elongate, sometimes unequal.

KEY TO GENERA OF **Tuberculariaceæ-Dematiæ-Amerosporæ**

Conidia not in chains
- Sporodochia not setose
  - Conidiophores lacking
    - Lichenicolous. . . . . 1. **Spilomium.**
    - Not lichenicolous
      - Sporodochia gelatinous; conidia globose, vesiculose. . . . . 2. **Myriophysa.**
      - Sporodochia not gelatinous
        - Sporodochia hemispheric, with a stratum of conidia . . . . . 3. **Spermodermia.**
        - Sporodochia disk-like, applanate. . . . . 4. **Sclerodiscus.**
  - Conidiophores present
    - Sporodochia thick, tremelloid. . . . . 5. **Epidochium,** p. 656.
    - Sporodochia not tremelloid
      - Conidiophores with a slender apical appendage; conidia globose . . . . . 6. **Bonplandiella.**

Conidiophores not appendaged
- Conidia globose
  - Sporodochia cellular, uniform 7. **Epicoccum,** p. 656.
  - Sporodochia of three hyphal layers. . . . . 8. **Triplicaria.**
- Conidia ovoid to bacillar
  - Conidiophores bacillar; sporodochia subdiscoid. . . . . 9. **Hymenopsis.**
  - Conidiophores branched
    - No brown radiate hyphæ at base. . . . . 10. **Strumella,** p. 656.
    - Brown radiate hyphæ at base. . . . . 11. **Astrodochilum.**

Sporodochia ciliate or with exserted hyphæ
- Sporodochia with loose exserted conidiophores, verruciform. . . . . 12. **Trichostroma.**
- Sporodochia margins with hairs or setæ
  - Setæ dark. . . . . 13. **Chætostroma,** p. 656.
  - Setæ or hairs white . . . . . 14. **Myrothecium.**

Conidia in chains
  Conidiophores lacking. . . . . 15. **Exosporina**, p. 656.
  Conidiophores present
    Sporodochia globose. . . . . 16. **Sphæromyces.**
    Sporodochia stellate. . . . . 17. **Actinomma.**

Epidochium Fries (p. 655)

Sporodochium thick, tremelloid, subglobose or wart-form, black or pallid, erumpent; sporophores filiform, equal or apically swollen; conidia ovoid, oblong or pyriform, solitary or catenulate.

Some fifteen species.

E. oryzæ Miy. is found [16] on rice.

Epicoccum Link (p. 655)

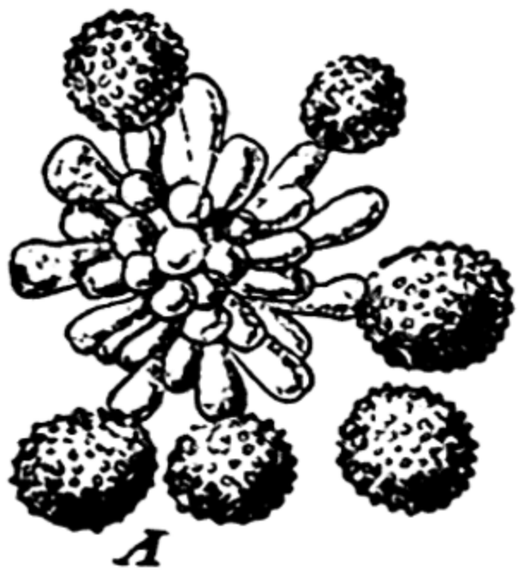


FIG. 445.—Epicoccum. After Saccardo.

Sporodochia globose or convex, cellular, dark; conidiophores very short; conidia globose. Some fifty species.

E. hyolopes Miy. is on rice.

Strumella Saccardo (p. 655)

Sporodochia wart-shaped; conidiophores branched; conidia ovate, often somewhat bent. Some fifteen species.

S. sacchari Cke. is found on sugar cane.[413]

Chætostroma Corda (p. 655)

Sori dark or cushion-form black bordered with black hairs; spores elliptical, fusiform or rarely almost spherical.

C. buxi Corda on Box = Nectria rousseliana. See p. 204.

C. cliviæ Oud. causes blotches on Clivia.

Exosporina Oudemaus

Sporodochia erumpent; conidia catenulate, homomorphic, continuous, greenish. Monotypic.

E. laricis Oud. is parasitic on larch leaves in Europe.

Tuberculariaciæ-Dematieæ-Phragmosporæ (p. 639)

Hyphæ dark; conidia usually colored, 2 to several-septate, oblong to cylindric.

KEY TO GENERA OF **Tuberculariaceæ-Dematiæ-Phragmosporæ.**

Conidia in chains; sporodochium discoid.	1. **Trimmatostroma,** p. 657.
Conidia not in chains	
Conidia 1-ciliate at each end.....	2. **Ciliofusarium.**
Conidia muticate	
Sporodochium hairy.....	3. **Excipularia.**
Sporodochium smooth	
Conidia laterally proliferate and joined in bundles.	4. **Amallospora.**
Conidia not proliferate and united	
Sporodochia convex-pulvinate..	5. **Exosporium,** p. 658.
Sporodochia vertically cylindric or clavate.....	6. **Listeromyces.**

Trimmotostroma Corda

Sporodochia pulvinate, compact, bearing a layer of conidiophores; conidia oblong, often curved, 2 to 8-septate, catenulate brown.

A genus of a half dozen species.

T. abietina Doh.[414]

Mycelium perennial; sporodochia foliicolus or caulicolus, diffuse; conidiophores subhyaline, or tinged with olive-brown, 4.5 x 20–30 μ, septate, sparsely branched, bearing the conidia terminally; conidia catenulate, very variable, dark olivaceous-brown, slightly roughened, usually oblong, spherical, straight or inequilateral, continuous, spherical, 5 μ, or 2 to 5-celled and 5–6 x 8--16 μ, not constricted, rarely muriform, 5 x 10 μ.

On white and balsam firs in Canada. The perennial habit of the mycelium makes the pest a persistent one and as no conidia are produced till the second year after infection its presence is the more readily overlooked.

Exposorium Link (p. 657)

Sporodochia convex, compact; conidiophores dark, simple, densely compacted; conidia single, oblong to cylindric, pluriseptate.

Some twenty-five species.

In part = Coleroa and Coryneum. See pp. 227, 236.

E. juniperinum (E.) Jacz. = Coryneum juniperinum. See p. 236.

E. laricinum Mas. is found on living larch twigs.

E. tiliæ Lk. grows on young shoots of Tilia.

E. palmivorum Sacc.[415]

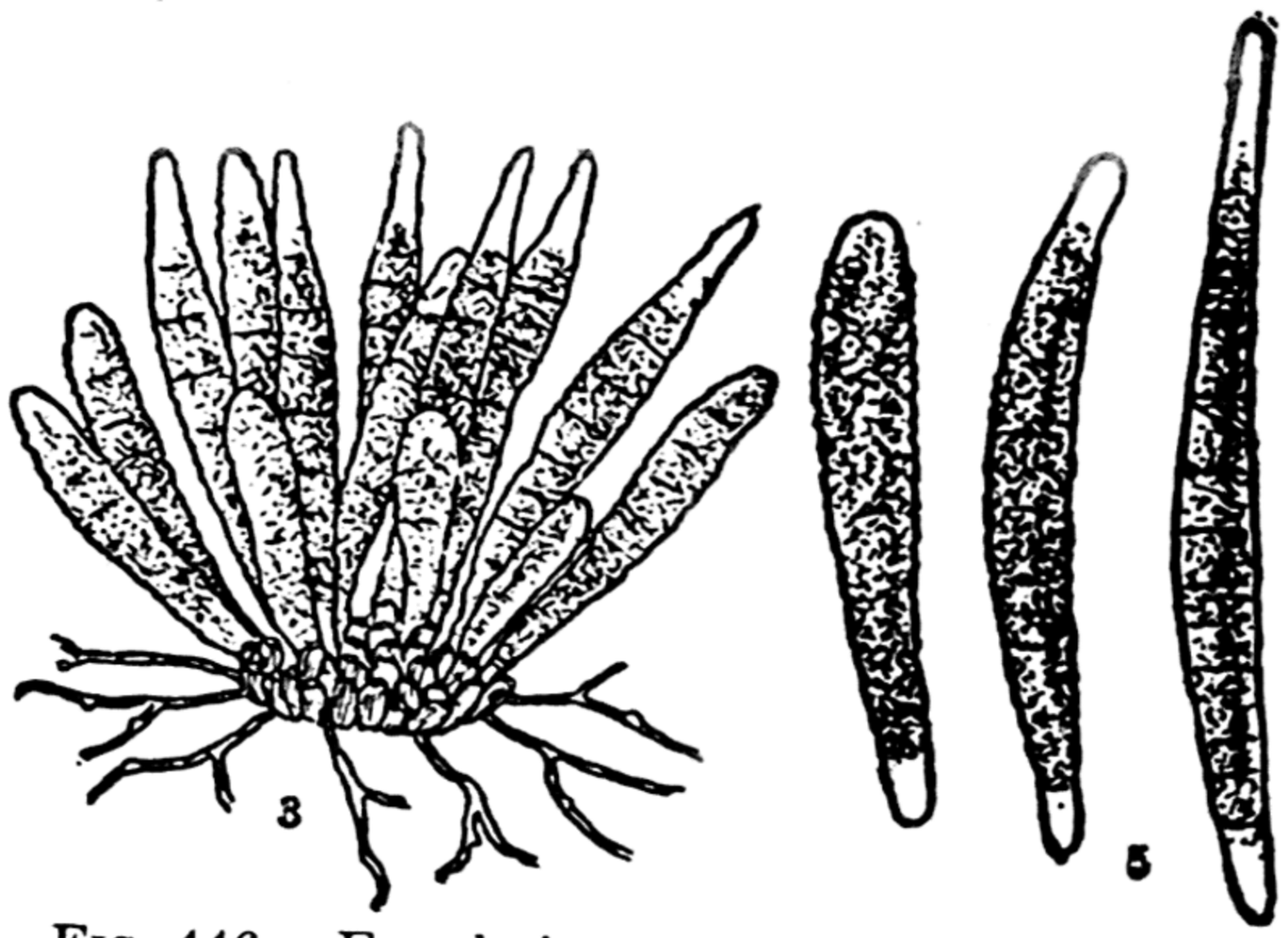


FIG. 446.—E. palmivorum. 3, a sporodochium, 5, spores. After Trelease.

Spots amphigenous, minute, suborbicular, 1–3 mm. in diameter, brown, scattered; sporodochia superficial, densely gregarious, punctiform, black; 30 x 60–80 μ; conidiophores oblong, continuous, reddish olive, 5–6 x 14–16 μ, conidia borne singly, fusoid, straight or curved, apically obtuse or acute, basally obtuse, 8 to 10–septate, not constricted, olive-brown, ends paler, 8–9 x 80–90 μ.

On palms, especially species of Phœnix in America.

E. presii Bub. on species of Phœnix in Europe is very similar to the preceding species.

In the Tuberculariaceæ-Dematieæ-Dictyosporæ **Thyrococcum sirakoffi** Bubak forms black tubercles under bark of mulberry and kills the twigs.[346]

Mycelia-Sterilia (p. 479)

Numerous forms are known merely as sterile mycelia. They may or may not make sclerotia. In several instances these sterile forms are so aggressive as to warrant classing them among the worst of plant pathogens. Until more is known of them it becomes necessary to arrange and name them, for convenience of reference, in a purely artificial manner.

Key to form Genera of Mycelia-Sterilia.

Tubercle-like	
Tubercles connected with fibrils.	1. **Rhizoctonia,** p. 659.
Tubercles without fibrils	
Cortex discrete.	2. **Acinula.**
Cortex not discrete.	3. **Sclerotium,** p. 660.
Maculiform	
Black stromata in leaves and stems.	4. **Ectostroma.**
Pseudo stromata in cortex.	5. **Phellomyces.**
Root-like	
Filaments rigid, broad, terete or depressed, dark, white within.	6. **Rhizomorpha.**
Filaments rigid, capilliform, dark, closely adhering.	7. **Capillaria.**
Clavariform; filaments terete, vertical, simple or branched.	8. **Anthina.**
Cobwebby or byssoid	
Cespitose interwoven, primary hyphæ joined in bundles.	9. **Ozonium,** p. 661.
Cespitose interwoven, hyphæ not fasciculate, black.	10. **Rhacodium.**
Cobwebby, soft, evanescent, white or pale	11. **Hypha.**
Adpressed, creeping, dendritic, white to brownish, not forming a continuous membrane.	12. **Himantia.**
Membrane-like; densely interwoven, forming a continuous suberose or coriaceous membrane.	13. **Xylostroma,** p. 663.

Rhizoctonia De Candolle

Sclerotia variable in form, horny-fleshy; cortex thin, mem-

branous, persistent, inseparable; formed among and connected by the mycelial threads.

There are about a dozen so-called species, some of them very important plant pathogens. See pp. 407, 408.

R. betæ Kühn and **R. solani** Kühn = Corticium vagum solani, as does also part of what has been referred to as R. violaceæ.

R. medicaginis D. C. (Tul.);[17] (see also [394, 416-417]).

Hyphæ subtomentose, on the cambium of the host, forming a membrane or fasciculate strands, covering the host in time with a violet coating; sclerotia reddish-violet.

On alfalfa in Europe and America.[419]

Duggar who has studied this form and the form allied to Corticium (pp. 407, 408) regards the two as distinct though Güssow [420] who has also studied both pronounces them the same. Duggar says, "The fungus appears upon the root as a close weft of violet-colored hyphæ composed of cells more or less uniform in diameter. Morphologically it bears no resemblance to the sterile stage of Corticium." This form is found on alfalfa, asparagus, beet, and possibly other plants.

Leptosphæria has been reported as its ascigerous stage though the evidence of such connection is not conclusive.

R. crocorum D. C. is a form which kills the corms of saffron.

R. strobi Scholz is the name given to a form described as seriously injuring young pine trees in Austria.[422]

R. subepigea Ber. is destructive on the roots of coffee.[424]

A Rhizoctonia of undetermined species has been found on buckwheat in the United States.[421]

Sclerotium Tode (p. 659)

Sclerotia roundish or irregular in form, cartilaginous-fleshy, not connected by mycelial threads; cortex thin, membranous, inseparable.

Over 200 species have been described.

S. rolfsii Sacc.[21, 425, 438]

Sclerotia small, brown, about the size of a mustard seed.

This sterile fungus possesses a very aggressive mycelium which under favorable conditions of moisture grows on almost anything living or dead, producing a dense white cotton-like mass of threads.

Soon the sclerotia form as mustard-seed-like bodies. They are produced in great abundance on all media but neither these structures nor the mycelium have yet been seen to bear spores of any kind. The fungus was first studied by Halsted [21] and later by many others. It was described and named by Saccardo from specimens communicated by Stevens.

S. cepivorum Berk.

Minute, spherical, gregarious, black. It is found on various species of Allium, causing rot.



FIG. 447.—S. rolfsii, sclerotia. After Halsted.

S. rhizoides Auer.[426]

Subglobose, at first white-villose, then smooth, black, rugose.

On Calamagrostis and other grasses. It causes considerable injury to the hay crop in Europe.

S. tuliparum Klebahn,[427] **S. tulipæ** Lib. and **S. bulborum** Wak. are found on tulips, and other bulbs. A relation to Sclerotinia is usually assumed but has not been demonstrated. See p. 136.

S. oryzæ Catt. is found on rice in Japan and Italy.

Ozonium Link. (p. 659)

Cobwebby or byssoid, cespitose, hyphæ densely interwoven, primary hyphæ fasciculate.

Some twelve species.

O. omnivorum Sh.[66, 428-43]

Mycelium dirty yellow; sometimes whitish when young, growing in the vascular bundles of the host; hyphæ forming strands and spreading from them, producing a rather dense arachnoid layer on the surface of the host and bearing 1 to 4 branches arising



FIG. 448.—S. rolfsii, sterile mycelium growing on carrot. After Stevens and Hall.

and growing at right angles from the same point near the ends, 3 to 5 μ in diameter, tapering toward the ends.

It causes root rot on almost any kind of plant including among its hosts a large variety of trees. The first description was by Pammel in a Texas Bulletin; a later one was by Shear. The fungus destroys the smaller rootlets, cortex of older roots and invades the vascular system and medullary rays, resulting in wilt and death. It may be seen as dirty yellowish strands or as a thin weft superficially. Sclerotia-like bodies appear on the roots often at

lenticels. Inside of the host tissue the mycelium is not typically associated to form strands and its cells are hyaline.

The fungus was in early studies difficult to isolate but Atkinson in 1893 [429] obtained pure cultures by rinsing the diseased roots in distilled water, cutting in small pieces and placing on sterile filter paper lying on sterile sand in a moist chamber. In a few days the strands grew over the paper onto sterilized slides. Bits of sterilized cotton-root were then placed in contact with the advancing hyphæ. Soon the new culture thus secured could be transferred at will. A slight acidity retards bacterial growth and renders isolation of the Ozonium less difficult. In culture sclerotia about 3 mm. in diameter, whitish and woolly, later brown, appear.

Xylostroma Todę (p. 659)

This occurs, forming thick, felt-like layers, in cracks of timber. It is regarded as the mycelium of various Hymenomycetes, especially Fomes.

Fungi of Unknown Affinity

The following imperfectly known genera do not fit readily into the scheme of classification and are all in need of careful study.

Acrocystis Ellis & Halsted

Monotypic; though technically a *nomen nudem*, the illustrations are recognizable. Examination of the original material shows Saccardo's reference to the Mucorales to be untenable.

A. batatæ E. & H.[54]

Hyphæ intercellular, branched, producing enlarged cysts at the ends of branches, the nature of these unknown; enlarged, intramycelial swellings contain numerous rounded conidia.

It is described as the cause of soil rot of sweet potatoes.

Graphiola Poit

Mycelium within the host; fruiting body rotund, carbonous duplex, the outer layer of interwoven branched hyphæ, firm, in-

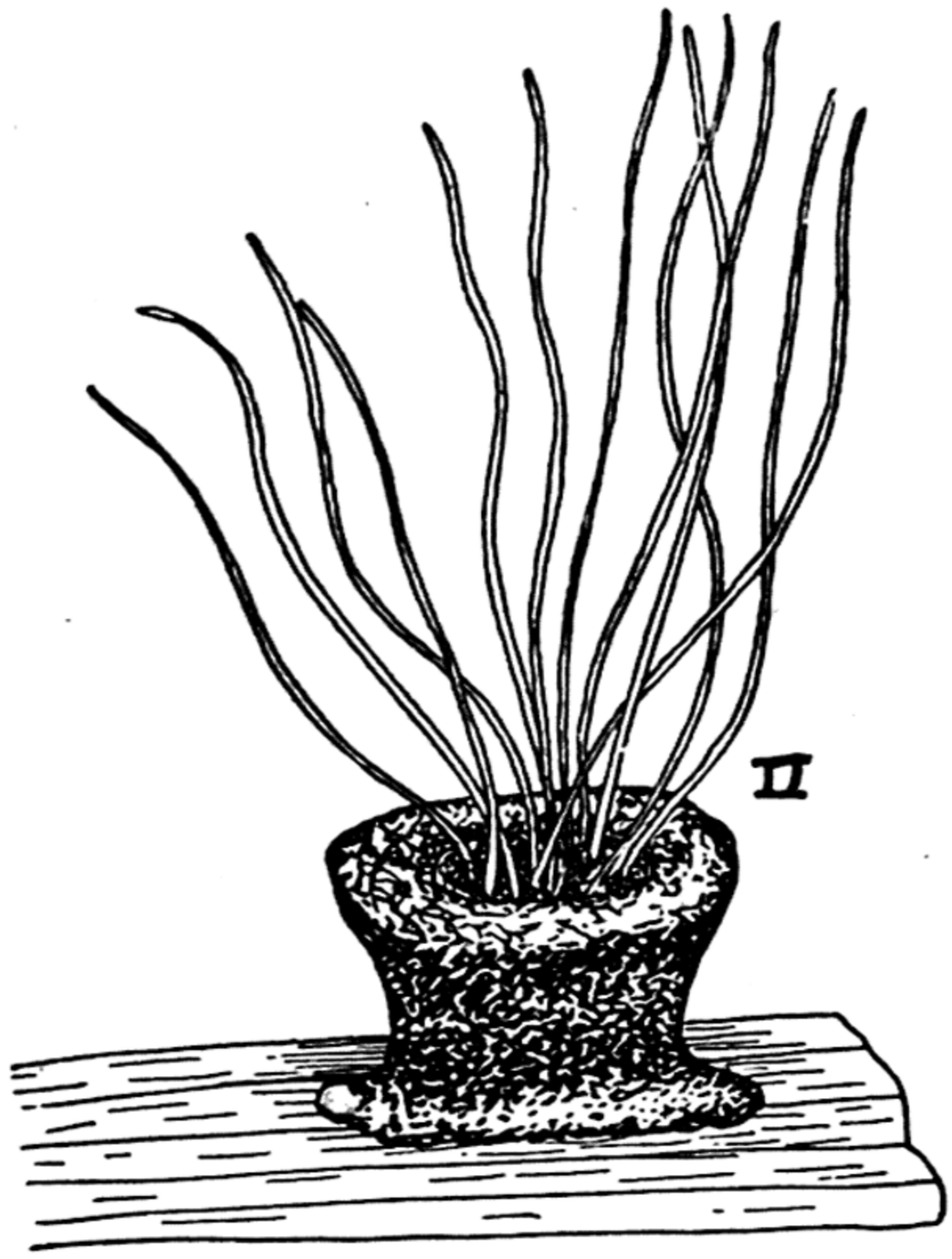
terior softer, of fertile and sterile fasciculate hyphæ; fertile hyphæ with short branches bearing the spore-mother-cells which divide into two globose or angular spores; germination by a filiform conidia-bearing mycelium.

A genus of seven species, chiefly on palms.

G. phœnicis (Moug.) Poit.[418, 439]

Sprodochium 1–1.5 x 500 μ; exoperidium horny, black, inner peridium membranous, hyaline; spore-mass yellow; spores globose or elliptic, 3–6 μ, with a thick, smooth, hyaline wall.

On the date and other palms throughout the world.



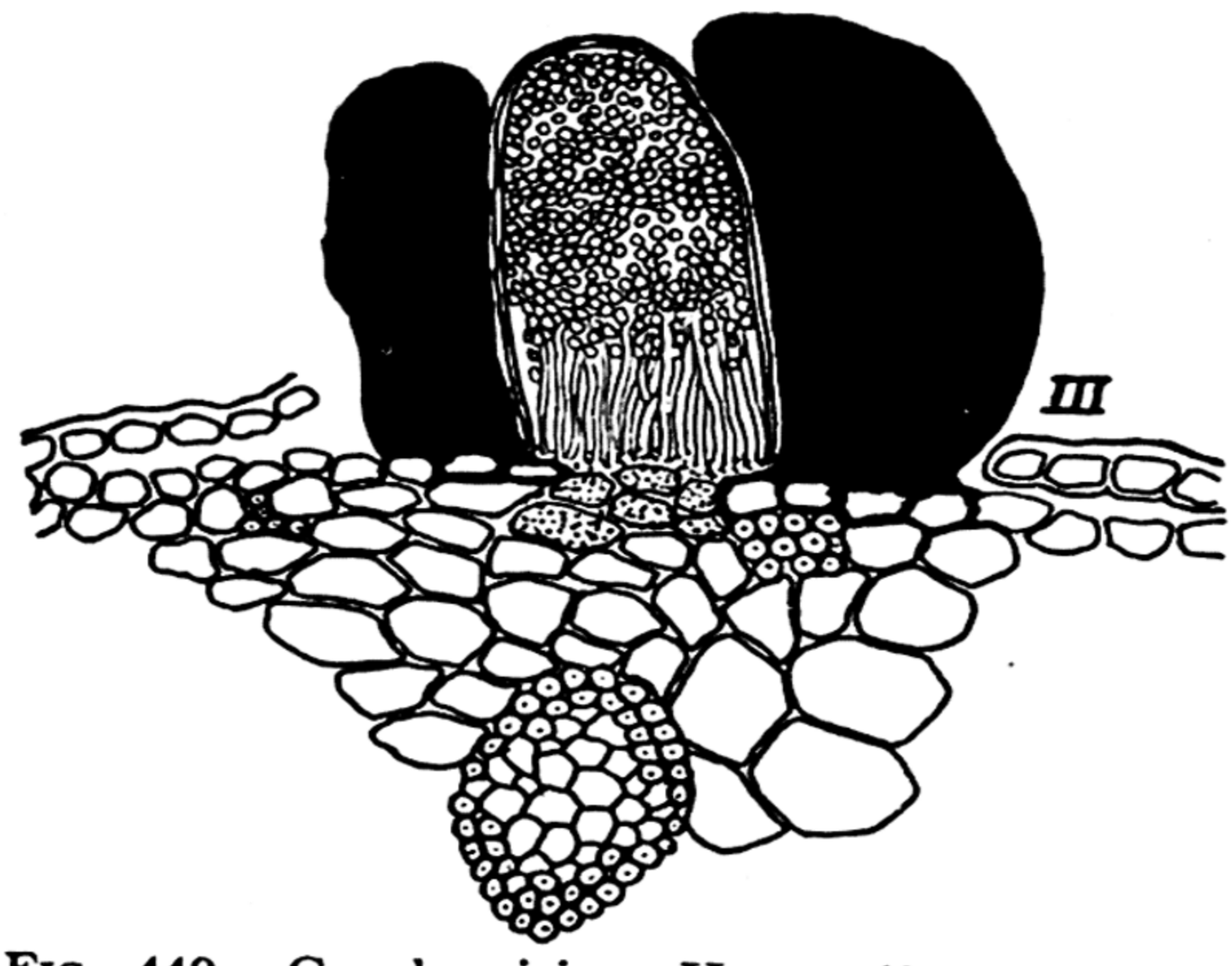


FIG. 449.—G. phœnicis. II, sporiferous organ. III, section of the same. After Stone and Smith.

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GLOSSARY

A

A, privative. Signifying without.
Acervulus (i). A small cluster, tuft of mycelium bearing spores.
Acicular. Slender or needle-shaped.
Acrogenous. Growing at the apex.
Acropetal. Produced in a succession towards the apex.
Adnate. Attached the whole length.
Æciospore. Æcidiospore. A spore formed in an æcium.
Æcium (a). Æcidum (a). A special form of sorus in the Uridinales.
Aërial. Living above the surface of the ground or water.
Aërobic. Aërobiotic. Requiring oxygen.
Æthalioid. Like an æthalium.
Æthalium (a). A compound sporiferous body formed from a large combination of plasmodia.
Agglutinated. Agglutinate. Glued together.
Aggregated. Aggregate. Collected together.
Allantoid. Sausage-shaped, crescent-shaped with rounded ends.
Alveola (æ). Cavities or pits on the surface. **Alveolate.** Pitted like a honeycomb. **Alveolar.** Pertaining to or resembling **Alveolæ.**
Amœboid. Like an amœba, exhibiting creeping movement by pseudopodia.
Amorphous. Shapeless.
Amphigenous. Growing all round an object, not restricted to any particular surface.
Ampulliform. Swollen out. Flask-shape.
Anastomosing. Uniting and forming a network.
Angiocarpous. Invested by some covering.
Annulate. Ring-shaped or with a ring.
Annulus. A ring-like portion of the ruptured marginal veil, after the expansion of the pileus.
Anoderm. Without a skin.
Antheridium (a). In fungi the male sexual organ.
Apical. At the point of any structure.
Apicula. A sharp and short, but not stiff point.

Apogamous. Showing apogamy.
Apothecium (a). An ascocarp in which the hymenium lies exposed while the asci are maturing.
Appendages. Processes of any kind.
Appendiculate. Furnished with appendages.
Appiculate. Furnished with an appicula.
Appressed. Lying flat for the whole length.
Appresoria. Organs of attachment of germinating parasites.
Approximate. Close together, but not united.
Arachnoid. Like a cobweb.
Arcuate. Curved.
Areola (æ). A space marked out on a surface.
Aristate. Awned.
Armilla. A bracelet-like frill.
Armilla-form. Armilla-like.
Ascigerous. Bearing asci.
Ascocarp. A sporocarp producing asci.
Ascogenous. Producing asci.
Ascogonium. In ascomycetous fungi, the cell or group of cells fertilized by a sexual act.
Ascoma. Receptacle and hymenium of the larger fungi.
Ascoplasm. Protoplasm of the ascus.
Ascus (i). A large cell in the ascocarp in which spores are developed, usually eight.
Aseptate. Without cross-divisions.
Asexual. Destitute of male and female organs.
Asperate. Rough with hairs or points
Attenuate. Tapered.
Auriform. Ear-shaped.
Autœcious. A parasite which runs its whole course on a single host.
Avellaneous. Drab, hazel, hazel-nut-brown.

B

Bacillar. Bacilliform. Rod- or club-shaped.
Basal. At the base of.
Basidiospore. A spore acrogenously abjointed upon a basidium.
Basidium. The mother-cell from which spores are acrogenously abjointed.
Basipetal. Growth in the direction of the base.
Bay. Reddish brown or chestnut color.
Biogenous. Growing on living organisms.

Botryose. Racemose.
Bullate. Blistered or puckered.
Byssoid. Flax-like or cottony.

C

Calcareous. Chalk-white, chalky.
Campanulate. Bell-shaped.
Cancellate. Latticed, as in Clathrus.
Capillitium. Sterile thread-like tubes or fibers, mixed with the spores within a sporangium.
Capitate. Having a head.
Carbonous. Carbonaceous. Dark colored. Consisting chiefly of substances in which carbon predominates.
Carpogonium (a). Part of a procarp resulting in a sporocarp after fertilization.
Cartilagenous. Hard and tough.
Castaneous. Chestnut-colored.
Catenulate. Concatenate. Formed of parts united or linked as in a chain.
Caulicolous. Living on stems.
Cespitose. Growing in tufts.
Chlamydospore. A spore having a very thick membrance.
Chromogenesis. Color production.
Chromogenic. Chromogenous. Color-producing.
Ciliate. Fringed with hairs.
Cilium (a). Vibratile whip-like processes of protoplasm by which zoöspores and similar bodies move.
Cinereous. Cineraceous. Ashy.
Circinate. Circinnate. Coiled into a ring or partially so.
Circumscissile. Dehiscing as if cut circularly around.
Cirrhose. Cirrose. Cirrhous. Having a cirrhus or tendril.
Clathrate. Latticed.
Clavate. Club-shaped, thickened towards the apex.
Clypeate. Buckler or shield-shaped, having a clypeus.
Clypeus. A buckler or shield-shaped tissue around the mouth of a perithecium.
Cœnocyte. A multinucleate cell.
Collabent. Collapsing.
Colliculose. With little round elevations.
Columella. Sterile axile body within a sporangium.

Columnar. Having the form of a column.
Compound. Similar parts aggregated into a common whole.
Con or Com. In Latin compounds signifying with.
Conchate. Shell-shaped.
Concolorous. Of one color.
Confluent. Blended into one.
Conglobate. Collected into a ball.
Conidiophore. A sporophore bearing a conidium.
Conidiospore. Same as conidium.
Conidium (a). Dust-like spores usually produced directly from the hyphæ.
Conjugation. Union of two like gametes to form a zygote.
Connate. United.
Constricted. Drawn together; contracted.
Context. The flesh of a mushroom and the corresponding substance in other pileate fungi.
Continuous. The reverse of interrupted.
Convoluted. Convolute. Rolled round.
Coremium. The name of a genus of fungi, derived from a Greek word meaning *broom*.
Coriaceous. Leathery.
Corneous. Of horny texture.
Cortex. The bark or rind. The peridium of Fungi.
Cortical. Relating to the cortex.
Costate. Ribbed.
Crateriform. Globet or cup-shaped.
Cristate. Crested.
Cruciate. Cross-shaped.
Crustose. Crust-like.
Cuboid. Resembling a cube.
Cupulate. With a cupule.
Cupuliform. Shaped like a small cup.
Cuticle. The outermost skin.
Cuticulate. Having a cuticle.
Cylindric. Cylindrical. Elongated, with a circular cross-section.
Cyme. Cluster of determinate or centrifugal type, especially a broad and flattened one.
Cyst. A sac or cavity.
Cystidium (a). Large, one-celled, sometimes inflated bodies, projecting beyond the basidia and paraphyses of the hymenium of Agarics.
Cytolitic. A ferment which dissolves the cell-wall.

D

Deciduous. Falling in season.
Decumbent. Reclining with the summit ascending.
Decurrent. Running down.
Definite. Precise; of a certain number.
Dehiscence. The mode of opening.
Deliquescent. Dissolving or melting away.
Dendritic. Having a branched appearance.
Dendroid. Tree-like in form, or branching.
Denticulate. Minutely toothed.
Depressed. Sunk down, flattened.
Determinate. Definite.
Di. Two or double.
Dichotomous. Forked.
Dichotomy. Forking in pairs.
Difform. Of double form, irregular.
Diffuse. Widely or loosely spreading.
Digitate. Fingered: compound. As in the Horse Chestnut leaf.
Dimidiate. Halved, as when half an organ is so much smaller than the other as to seem wanting.
Disciform. Flat and circular.
Discoid. Resembling a disk.
Disculate. Having a disk.
Disjunctors. Spindle-shaped cellulose connections between conidia.
Dissepiment. A partition.
Doliform. Barrel-shaped.

E

E, Ex. Privative in Latin compounds.
Echinulate. Having small prickles.
Effuse. Expanded.
Ellipsoid. Ellipsoidal. Elliptic. Like an ellipse.
Embedded. Surrounded in.
Endogenous. Produced within.
Endophyte. Growing inside another plant.
Endophytic. As an endophyte.
Endospores. Spores formed endogenously.
Endozoic. Living inside an animal.
Entire. With even margin.

Entomogenous. On insects.
Enzyme. An unorganized or soluble ferment.
Epi. In Greek compounds to mean " upon "
Epiphyllous. Growing on leaves.
Epispore. Outer coat of a spore.
Epithecium. The surface of the fructifying disk.
Epixylous. Growing on wood.
Erumpent. Breaking through.
Evanescent. Soon disappearing.
Excipuliform. Wart-like.
Exospore. The outer covering of the spore.
Explanate. Spread out flat.
Exserted. Protruding beyond.

F

Facultative. Occasional, incidental as opposed to obligate.
Falcate. Sickle-shaped.
Fascicle. A little bundle.
Fasciculate. In clusters or bundles.
Favoid. Like a honeycomb.
Ferruginous. Ferrugenous. Ferrugineous. Rust-colored.
Fibrillous. Fibrillose. Furnished with fibers.
Filamentous. Of free hyphæ which are at most loosely interwoven but without forming bodies of definite shape and outline.
Filiform. Thread-shaped.
Fimbriate. With the margin bordered by long slender processes.
Fission. Splitting.
Flabelliform. Shaped as a fan.
Flaccid. Limp, flabby.
Flagellate. Provided with whip-like processes.
Flagellum (a). Whip-like process of protoplasm of a swarmspore.
Flavous. Nearly pure yellow.
Fleshy. Succulent.
Flexuose. Flexuous. Bent alternately in opposite directions, zigzag.
Flocci. Locks like soft hair or wool.
Floccose. Bearing flocci.
Flocculent. Diminutive of **Floccose.**
Fluorescence. The property of diminishing refrangibility.
Fluorescent. Exhibiting fluorescence.
Fœtid. Fetid, stinking.

Foliar. Leafy or leaf-like. On a leaf.
Foliicolous. On leaves.
Free. Not adhering.
Fructicolous. Living on fruit.
Fruticolous. Living on shrubs.
Fruticose. Shrubby.
Fugacious. Soon perishing.
Fuligineus. Fuliginous. Sooty, or soot-colored.
Fulvous. Yellow, tawny.
Fumaginous. Smoky; sooty.
Furcate. Forked.
Fuscous. Dusky, too brown for a gray.
Fusiform. Thick but tapering towards each end.
Fusoid. Somewhat fusiform.

G

Gametangium (a). A differentiated cavity, whic.. produces gametes.
Gamete. A sexual protoplasmic body.
Gemma (æ). A young bud.
Gemmation. Budding.
Gemmiform. Bud-shaped.
Gill. The plates or lamellæ of an Agaric.
Glabrous. Without hair.
Gleba. The gelatinous spore mass in the Phallales.
Globoid. Rounded.
Globose. Nearly spherical.
Glomerate. Agglomerate, collected into heads.
Granular. Composed of grains.
Gregarious. Growing in company. Associated but not matted.
Guttulate. Resembling drops, with drops.
Gymnocarpous. Naked fruited.
Gyrose. Curved backward and forward in turn.

H

Hamate. Hooked at the tip.
Haustorium (a). Special branch of a filamentous mycelium serving as an organ of attachment and suction.
Heterœcism. Condition of a heterœcious parasite.
Heterœcious. Passing its stages on more than one host.
Heterogamy. With gametes not uniform.

Heteromorphic. Heteromorphous. Variation from normal structure, as having organs differing in length; dimorphic.
Hirtose. Hirtus. Hairy; hirsute.
Hispid. Bristly.
Hoary. Gray from fine pubescence.
Host. A plant which nourishes a parasite.
Hyaline. Colorless or translucent.
Hyaloplasm. The hyaline matrix or clear non-granular portion of protoplasm.
Hymenium (a). An aggregation of spore mother-cells in a continuous layer on a sporophore.
Hymenophore. That part which bears the hymenium.
Hypha (æ). The thread-like vegetative part of a fungus.
Hyphoid. Resembling hyphæ.
Hypertrophy. An abnormal enlargement of an organ.
Hypophyllous. Situated under a leaf.
Hypopodium (a). The stalk or support.
Hypothallus. The marginal outgrowth of hyphæ often strand-like, from the thallus.
Hypothecium. A layer of hyphal tissue immediately beneath the hymenium.
Hysterioid. Elongated boat-shaped, resembling the genus Hysterium.

I

I, II, III. Symbols for the stages of the rusts, see p. 324, 326.
Imbricate. Overlapping as the tiles on a roof.
Immersed. Below the surface.
Imperforate. Without an opening.
Incrassation. Thickened growth.
Indehiscent. Not opening along regular lines.
Indeterminate. Not terminated definitely.
Indurate. Hardened.
Infundibuliform. Shaped like a funnel.
Innate. Born on the apex of the support. Imbedded.
Intercalary. Growth which is not apical but between the apex and the base.
Intercellular. Between cells.
Intracellular. Inside a cell.
Intramycelial. Within the mycelium.
Involute. Enwrapped, having the edges of the leaves rolled inwards.
Irpiciform. Having teeth resembling those in Irpex.

Isabelline. A dirty tawny tint.
Isogamous. Used for those plants which produce like gametes.
Isogamy. Conjugation of two gametes of similar form.

K

Keeled. Carinate.

L

Labyrinthiform. Marked by sinuous lines.
Lacerate. Torn, or irregularly cleft.
Lactiferous. Latex bearing.
Lamella (æ). The gills of Agaricales.
Lamellate. Made up of thin plates.
Lamelliform. In the shape of a plate or scale.
Lamelloid. Resembling lamellæ.
Lageniform. Shaped like a Florence flask.
Lanceolate. Narrow, tapering to each end.
Latericious. Lateritious. Brick-red.
Latticed. Cross-barred.
Lax. Loose, distant.
Lenticular. Shaped like a double convex lens.
Lichenoid. Irregularly lobed as lichens.
Lignicole. Growing on wood.
Limoniform. Lemon-shaped.
Linear. Narrow, several times longer than wide.
Lipochrome. A yellow pigment.
Lobate. Lobed. Divided into or bearing lobes.
Locule. Loculus. A cell or cavity.
Lumen. The space which is bounded by the walls of an organ, as the central cavity of a cell.

M

Macro. Mega. In Greek compounds to signify large.
Maculicole. On spots.
Mammiform. Breast-shaped.
Marginate. Broad-brimmed, furnished with a margin of distinct character.
Matrix. The body on which a Fungus or Lichen grows.
Melleus. Melleous. Like honey.

Membranous. Membranaceous. Thin and semi-transparent, like a fine membrance.
Medullary. Relating to the pith, pithy.
Micro. To signify small, little.
Microsporangium (a). A sporangium which produces microspores.
Mon. In Greek compounds to signify one.
Monopodium (a). An axis which continues to grow at the apex in the direction of previous growth, while lateral structures of like kind are produced beneath it in acropetal succession.
Monosporic. Bearing one spore.
Monostichous. In a single vertical row.
Mucose. Slimy.
Multi. A Latin element signifying many or much.
Muricate. Rough with short hard excrescences.
Muriculate. Diminutive of Muricate.
Muriform. With cells resembling bricks in a wall, with both longitudinal and transverse septa.
Muticous. Muticate. Pointless, blunt.
Mycelium. Vegetative portion of thallus of fungi composed of one or more hyphæ.
Myxamœba (æ). Swarm-cells with purely amœboid creeping motion.

N

Nodose. Knotty or knobby.
Nodule. A small knot or rounded body.

O

O. A symbol for the pycnial stage of the rusts.
Ob. As a prefix meaning inversely or oppositely.
Obese. Excessively fat; fleshy.
Obligate. Necessary, essential. Comp. Facultative.
Obsolete. Wanting or rudimentary.
Ochraceous. Ocher-colored, yellow with a tinge of red.
Olivaceous. The color of a ripe olive.
Oögonium. Female sexual organ, containing one or more oöspheres.
Oösphere. Naked mass of protoplasm which, after fertilization, develops into the oöspore.
Oöspore. Immediate product of fertilization of oösphere.
Opalescent. Reflecting an iridescent light.
Operculate. Furnished with a lid.

Operculum. A lid or cover which separates by a transverse line of division.
Opt. Abbreviation for Optimum.
Ostiolate. Bearing an ostiole.
Ostiole. An opening or mouth.
Oval. Broadly elliptic.
Ovate. Shaped like a longitudinal section of a hen's egg.
Ovoid. Resembling an egg.

P

Pannose. Felt-like.
Papilla (æ). Soft superficial protuberances.
Papillate. Having papillæ.
Papilliform. Shaped like a papilla.
Papilloid. Resembling a small nipple.
Paraphysate. With paraphyses.
Paraphyses. Sterile filaments occurring in the fructification of cryptogams.
Parasite. An organism living on or in and at the expense of another living organism (the host).
Patellate. Shaped like a patella.
Patelliform. Like a small dish, circular and rimmed.
Pedicel. The support.
Pedicellate. Borne on a pedicel.
Pellicle. A small skin; a delicate superficial membrane.
Pellucid. Wholly or partially transparent.
Penicillate. Like a little brush. Pencil-shaped.
Perforate. Pierced through.
Peridium. The outer enveloping coat of a sporangium.
Periplasm. The protoplasm in the oögonium and the antheridium which does not share in conjugation.
Perithecium. A rounded, oval, pyriform or beaked structure in which asci are borne.
Peritrichiate. With hairs from all of surface.
Persistent. Remaining till the part which bears it is wholly matured.
Phycochrome. The coloring matter of brown Algæ.
Phyllogenous. Growing upon leaves.
Phytogenous. Growing on plants.
Pileate. Having the form of a cap.
Pileiform. Pileus-shaped.
Pileus. Cap. The dome-shaped part of a sporophore.

Pilose. Pilous. Hairy, having soft and distinct hairs.
Planose. Plane.
Plasmodiocarp. An asymmetrical sporangium of the Myxogastres.
Plasmodium. Body of naked plurinucleated protoplasm exhibiting amœboid motion.
Pleurogenous. Growing from the sides.
Plexus. A network.
Plicate. Folded into plaits usually lengthwise.
Polar. Relating to the poles of an organ.
Polymorphic. Polymorphous. With several or various forms, variable as to habit.
Polysporic. Many spored.
Porcelaneous. Like porcelain.
Poroid. Resembling pores.
Porose. Containing pores.
Proliferous. Bearing offshoots.
Promycelium. Short and short-lived product of tube-germination of a spore which adjoins acrogenously a small number of spores (sporidia) unlike the mother-spore and then dies off.
Pseudo. In prefix signifying false, counterfeit, spurious.
Pulverulent. Powdered, as if dusted over.
Pulvinate. Cushion-shaped.
Punctiform. In the form of a point or dot.
Punctulate. Marked with small points.
Pustular. Blister-like, bearing blisters.
Pustule. A pimple or blister.
Pustuliform. Having slight blister-like elevations.
Putrescent. Becoming rotten.
Pycnidium (a). A variously shaped cavity resembling a pyrenocarp and containing conidia.
Pycniospore. Spores borne in pycnia.
Pycnium. A structure of the Uridinales; see pp. 324–326.
Pycnosclerotia. Sclerotia bearing pycnidia.
Pycnospores. Spores from pycnidia.
Pyriform. Piriform. Resembling a pear in shape.

R

Radiate. Spreading from or arranged around a common center.
Ramicole. Growing on branches.
Ramose. Branched.
Receptacle. That part which bears one or more organs.

Reniform. Kidney-shaped.
Resupinate. Without a pileus.
Reticulate. Netted, like network.
Revolute. Rolled back from the margin or apex.
Rhizoid. A root-like structure.
Rhizomorph. A root-like branched strand of mycelial hyphæ.
Rhomboidal. Approaching a rhombic outline.
Rimose. Rimous. Cracked.
Rostrate. With a beak.
Rostrum. Any beak-like extension.
Rufous. Reddish.
Rugose. Rugous. Covered with wrinkles.

S

Saccate. Bag-shaped.
Saprophyte. A plant living on dead organic substance.
Sarcinæform. Having the form of the genus Sarcina.
Scabrous. Rough to the touch.
Sclerotioid. Like a sclerotium.
Sclerotium. A compact mass of hyphæ in dormant state.
Scopulate. Broom-like or brush-like.
Scorpioid. With the main axis coiled like the tail of a scorpion.
Scrupose. Jagged, rough.
Scutiform. Buckler-shaped.
Septate. Divided by a partition.
Septum (a). Any kind of partition.
Seriate. In a series.
Sessile. Destitute of a stalk.
Seta(æ). A bristle or bristle-shaped body.
Setaceous. Bristle-like.
Setose. Bristly, beset with bristles.
Setulose. Resembling a fine bristle.
Shield-shaped. In the form of a buckler; clypeate, peltate, or scutate.
Sigmoid. Doubly curved in opposite directions, like the Greek sigma.
Simple. Of one piece or series, opposed to compound.
Sinuous. Sinuose. Sinuate. With a deep wavy margin.
Sorus (i). Heap, or aggregation; a heap of spores.
Spatulate. Like a druggist's spatula.
Sperm. A male reproductive cell.
Spermatum (a). Male non-motile gamete, sometimes erronously used for various conidia.

Sphæroidal. Somewhat spherical.
Spindleform. Spindle-shaped, fusiform.
Sporangiophore. A sporophore bearing a sporangium.
Sporangium. Sac producing spores endogenously.
Spore. A single cell which becomes free and is capable of developing directly into a new plant.
Sporidium. Diminutive of spore, especially applied to the spores produced on promycelia.
Sporocarp. A many-celled body serving for the formation of spores.
Sporodochium. The sporiferous apparatus in fungi belonging to the Tuberculariales.
Sporogenous. Producing spores.
Stellate. Star-shaped or radiating like the points of a star.
Sterigma (ta). A stalk-like branch of a basidium bearing a spore.
Stipe. A general term for stalk.
Stipitate. Having a stipe.
Stolon. A sucker or runner.
Stoloniferous. Bearing stolons.
Stratose. In distinct layers.
Striate. Marked with fine longitudinal parallel lines.
Strigose. With sharp-pointed appressed straight and stiff hairs or bristles.
Stroma (ta). A cushion-like body, on or in which the perithecia are immersed.
Stromatic. Pertaining to or resembling a stroma.
Stuffed. Solid, farctate.
Stylospore. A spore borne on a filament.
Sub. Under or below; in compounds usually implies an approach to the condition designated; somewhat or slightly.
Subiculum. Subicle. A felted or byssoid basal stratum of hyphæ.
Subulate. Awl-shaped.
Sulcate. Grooved or furrowed.
Superficial. On the surface.
Suspensor. A club-shaped or conical portion of hypha adjoining a gamete-cell.
Sympodium. An axis made up of the bases of a number of successive axes arising as branches in succession one from the other.
Syn. Signifies adhesion or growing together.
Synema. A column of combined filaments.

T

T. D. P. Abbreviation for Thermal-death-point.
Teleutospore. A resting spore of Uridinales on germination producing a promycelium.
Teleuto-stage. Stage producing a teleutospore.
Telium. A sorus of the Uredinales; see pp. 324–326.
Terete. Circular in transverse section.
Ternate. In threes.
Thalloid. Having the nature or form of a thallus.
Thallus. A vegetative body without differentiation into stem and leaf.
Tomentose. Densely pubescent with matted wool, or short hairs.
Tortuous. Bent or twisted in different directions.
Torulose. Irregularly bending. Somewhat moniliform with swollen portions.
Tremelliform. Gelatinous in texture.
Tremelloid. Jelly-like in substance or appearance.
Trichogyne. The receptive filament of the female organ.
Trident. Having three teeth.
Triquetrous. Three-edged, with three salient angles.
Truncate. As though cut off at the end.
Tubercular. Having tubercles, or like a tubercle.
Tuberculate. Beset with knobby projections or excrescences.
Tubular. Cylindrical and hollow.
Tumid. Inflated, swollen.

U

Umbellate. Having the inflorescence in umbels.
Umbilicate. Navel-like.
Umbo. A boss.
Umbrinaceous. Umbrinous. Umbrinus. Umbrinose. The color of raw umber.
Uncinate. Hooked.
Ungulate. Having claws or hoofs.
Unguliform. Hoof-shaped.
Uni. In composition, one, or single.
Urceolate. Urceolar. Pitcher-like, hollow and contracted at the mouth like an urn.
Uredinium. A sorus in the Uredinales, see pp. 324–326.

V

Vacuolate. Possessing vacuoles.
Valsoid. Resembling Valsa.
Valvate. Opening by valves.
Vegetative. Growing.
Veil. A special envelope in Agaricales within which the growth of the sporophore takes place.
Velutinous. Velvety, due to a coating of fine soft hairs.
Vermicular. Vermiculate. Worm-shaped, thickened and bent in places.
Verruciform. Wart-shaped.
Verrucose. Verrucous. Verruculose. Full of warts. Warty.
Verticillate. Whorled.
Vesicular. Composed of vessels.
Villi. Long weak hairs.
Villous. Bearing villi.
Vinose. Vinous. Wine colored.
Viscid. Sticky from a tenacious coating or secretion.
Volva. A covering, the sac enclosing the Agaric sporophore.

Z

Zonate. Marked circularly.
Zoöglœæ. A colony embedded in a gelatinous substance.
Zoösporangia. Sporangia which produce zoöspores.
Zoöspore. A motile spore,

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